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Contribution of the E33 Hood to Heat Stress on Men Wearing CBR Protective Clothing

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U. S. ARMY
Chemical Corps Research and Development Command
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FOREWORD

These tests were authorized under Task 4C80-01-005-01, Biological Aspects of CW Protection, and the Development Test Plan for Hood, Field Protective Mask, E33 (U). The observations were made during August, September, and October of 1960.

Acknowledgments

The authors are indebted to Pfc Martin Potzler and Pfc Morris Rooker of Protective Development Division, Directorate of Development, CRDL, who volunteered as test subjects. Their completion of the entire series of tests according to plan demonstrated the outstanding cooperation and devotion to duty of these men. The authors are also indebted to A. L. West and E. Sovinsky of the same division for their support of this work and for critical review of the manuscript. Valuable technical assistance was rendered by W. V. Blevins, P. Edgar, C. R. Bulette, V. M. Seabaugh, J. McHugh, and E. Erickson of the Applied Physiology Branch.

DIGEST

The E33 hood attached to the M17 mask provides CBR protection to areas of the head, neck, and shoulders not covered adequately by the mask and the remainder of the CBR protective field uniform. The physiological evaluation of the hood was undertaken with the objective of measuring the increment in heat stress produced by the hood when added to the protective assembly under conditions of moderately hard work in hot-humid weather, and the contribution of sunshine to the heat stress. The latter information is needed for determining laboratory conditions that will produce heat stress comparable with that of outdoor conditions.

The conclusions are as follows:

1. The E33 hood adds measurably to the heat stress of the CBR protective assembly. The added stress at an environmental temperature of 85°F is about two thirds that of sunshine and about one half that of an increase in the marching speed from 2 to 3 mph.

2. The hood does not interfere with the performance of muscular work of moderate intensity. In the hardest work, the voluntary tolerance time is decreased about one fourth.

3. The heat strain in men working in CBR protective clothing at a given temperature outdoors in the sun can be duplicated indoors at a room temperature 10°F higher than the outdoor temperature.

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CONTRIBUTION OF THE E33 HOOD TO HEAT STRESS
ON MEN WEARING CBR PROTECTIVE CLOTHING

I. INTRODUCTION.

The hood, field protective mask, E33[1-3] is made of cloth with an impermeable coating and covers the head and neck (figures 1 and 2). It attaches to the M17 mask and continues into a skirt that fits over the shoulders and is secured by straps that pass under the arms. The hood and mask form part of the chemical, biological, radiological (CBR) protective assembly worn by the soldier in the field in addition to the impregnated field uniform and impregnated two-piece long underwear. The hood covers about 2 sq ft of the neck and shoulders, not counting the areas covered by the mask and helmet.

The purpose of this work was to measure the increment in heat strain produced by the hood when added to the protective assembly under conditions of moderately hard work in hot-humid weather and to measure the contribution of sunshine to the heat stress under the same conditions.

Precursors of the E33 hood were tested by Robinson and Gerking in 1945.[4] Subjects exercised at a metabolic rate of 164 Cal/sq.m/hr and wore the herringbone twill jungle uniform with no mask, with mask, with mask plus permeable hood, and with mask plus impermeable hood. At 86°F and 80% relative humidity, the sweat production was 742, 815, 864, and 950 gm/hr, respectively. In 1948, Marzulli, Stubbs, and Craig[5] compared the permeable (E26R14) and impermeable (E10) hoods. The men were wearing the two-layer permeable protective outfit plus the M9 mask and the steel helmet at 85°F and 71% relative humidity at about the same metabolic rate as given previously.[4] Under these conditions the sweat production was 1,200 gm/hr for the permeable hood and 1,190 gm/hr for the impermeable hood. A difference between the two hoods of the size found by the earlier workers was not detected because the helmet covered a large area of the head, and the area covered only by the hood was small.

In tests with troops at Ft. McClellan, Alabama, in June and July 1959, one group wore the M17 protective mask and field uniform; another group wore a two-layer permeable protective outfit including the M17 mask, the E33 permeable hood, and long underwear. The work was hard (handling of smoke generators and oil drums), temperatures were in the high 90's, relative humidity was about 50%, and the men were exposed to the sun. Under these conditions the amount of work performed was less in the second group than in the first.[6]

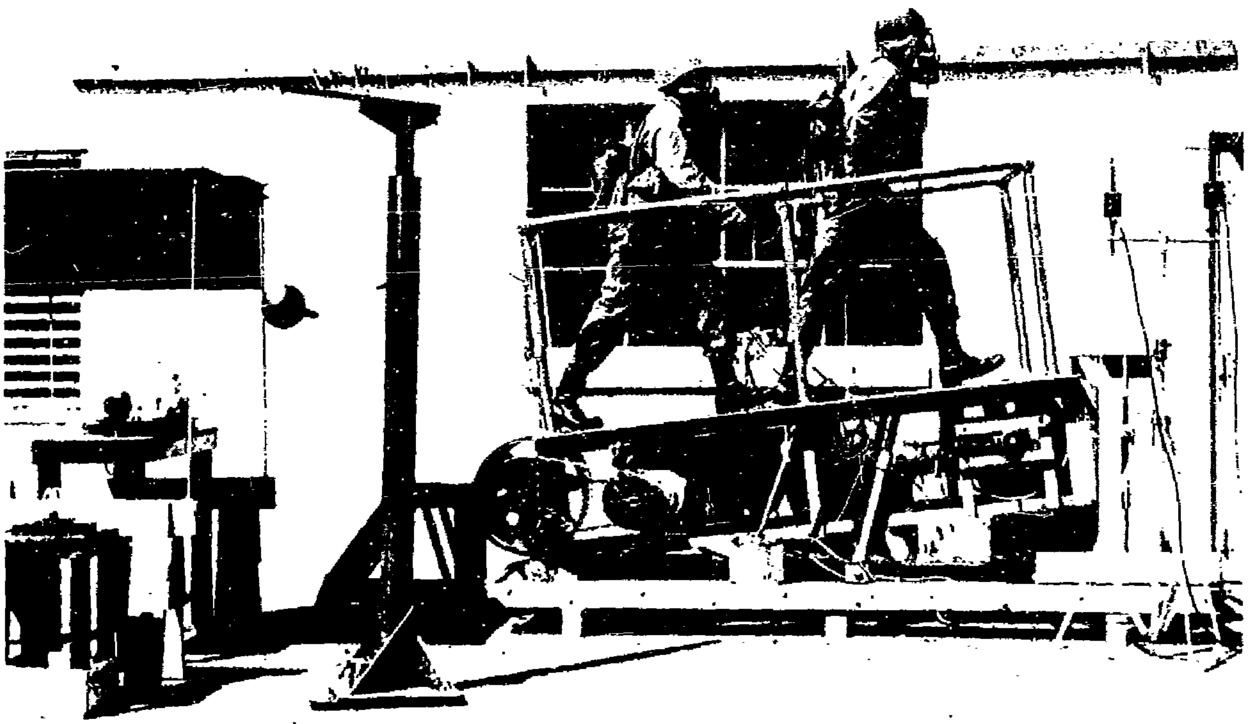

FIGURE 1

VIEW OF OUTDOOR SITUATION LOOKING NORTH

Treadmill is on 12% grade; forward man is wearing hood; wind instrument stands at right, pyrheliometer mounted on wooden frame stands at extreme left, motor-driven psychrometer rests on table in shade, globe thermometer hangs in sun

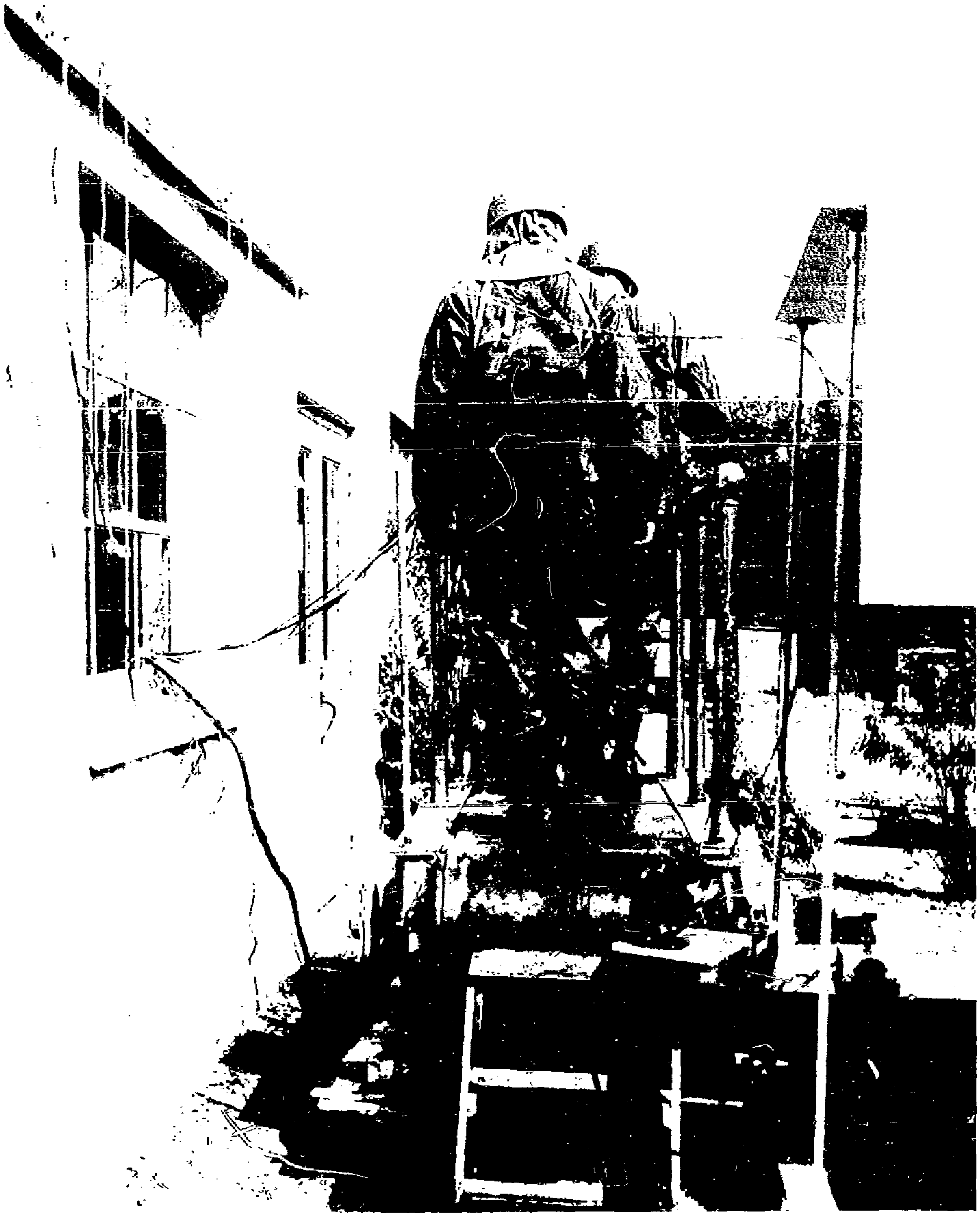

FIGURE 2

VIEW OF OUTDOOR SITUATION LOOKING EAST

Treadmill is level; rear man is wearing hood; motor-driven psychrometer stands in foreground with leads to recording instruments passing through hole in window

Some such effect might have been predicted from the results of Robinson and Gerking.[4] However, the environmental conditions in Alabama were more severe than those in the other tests cited, and the area of the shoulders covered by the E33 hood is greater than that covered by the hoods tested earlier. Much of the decrease in work performance seen in Alabama can be attributed to the underwear. Woodward and Cummings[7] found a distinct increase in heat strain when long impregnated underwear was substituted for a T-shirt and shorts in otherwise identical assemblies that included a protective mask, hood, and cotton gloves. The determination of the share of the decrease in work performance attributable to the E33 hood remained an object of the present test.

To set up comparable environmental conditions presented some difficulty, as the outdoor temperatures at Army Chemical Center at the time were 10°F or more lower than those in Alabama. While any temperature could be obtained in the hot room, it was not known how to compensate for the lack of sunshine indoors under the conditions of high humidity and protective clothing. Previously, Adolph and Molnar[8] measured the physiological responses to exposure at a series of temperatures below 80°F in the sun and in the shade of men at rest wearing a minimum of clothing. Shade temperatures produced the same effects as sun temperatures about 12°F lower than the shade temperatures. Also, Gosselin[9] measured the sweating rates of men wearing herringbone twill fatigue uniforms walking in the desert at night and during the day in the sun at temperatures ranging from 90° to 110°F. The sunshine had the same effect as an increase in the temperature at night of about 10°F.

We decided to use the test subjects as thermometers and, while keeping the humidity constant, to vary the temperature in the hot room until the same physiological response was obtained indoors and outdoors. The increment in dry-bulb temperature required to compensate for the lack of sunshine could then be added to the temperature reported from Albama. This would establish the hot-room temperatures that could be expected to produce physiological responses similar to those seen in Alabama.

The rate of heat storage in the body represents the difference between the heat produced in metabolism and the heat lost from the body. Heat storage is an index of physiological heat strain arising from the stresses of work, clothing, and environmental conditions of heat and humidity. Heat strain is manifested also by increases in sweat production and in frequency of the heart beat. When the stress is too small to produce heat storage, pulse frequency and sweating indicate the degree of heat strain. In present tests the heat stress was great, and heat storage has been adopted as the most useful index of physiological strain.

II. PROCEDURE.

The subjects were two college-educated enlisted men who volunteered for this duty. In order to minimize variations in daily routine that could be expected to modify their performance, they were relieved of all other details and military assignments during the testing period. Their physical characteristics are given in table 1. In the acclimatization period before the collection of data was begun, P had 11 days and R had 7 days of training with the clothing and the treadmill exercise at 85°F, including 3 days on the outdoor treadmill. Data were collected on 16 days outdoors at an average temperature of 85°F. When the weather turned colder, the tests were continued indoors for 4 days at 100°F, 8 days at 115°F, and finally, for 4 days at 85°F. The extra days at 115°F were used to repeat some incomplete experiments and to try the effect of allowing the expired air to vent outside the hood. In all the other tests, the expired air was vented inside the hood. The tests was begun at 1300 hours, Eastern daylight time. On half the days the men were scheduled to walk for 55 minutes at 3 mph on the level, take 5 minutes out for weighing, and continue in a second walk for 55 minutes at 3 mph on the level. On the other days the men were scheduled to walk for 55 minutes at 2 mph on the level, take 5 minutes for weighing, and continue in a second walk at 3 mph up a 12% grade for 15 minutes.

TABLE 1

PHYSICAL CHARACTERISTICS OF SUBJECTS

Subject	Height	Weight	Surface area	Age	Ethnic group
	cm	kg	sq m	yr	
P	180	80	2.00	24	Caucasoid
R	175	72	1.86	24	Negroid

List 1 gives the clothing and associated equipment worn by the subject. The total weight of clothing and equipment was 36 pounds. The hood was worn on alternate days; each day one subject wore the hood and the other did not. The outlet from the mask was into the hood.*

* Inadvertantly the gloves were omitted, and when this was noticed it was decided to keep on without them to avoid introducing a variable in the middle of the series. Also, unintentionally, P's helmet liner had a glossy painted surface and R's had a dull finish.

LIST 1

CLOTHING ASSEMBLY

Utility jacket, bloused

Utility trousers

Drawers, long, cotton and wool*

Shirt, underwear, long, cotton and wool*

Socks, wool, cushion sole

Mask, protective, M17

Helmet liner

Pistol belt

Pack, 20 pounds

Thermocouple supports, three

Rectal thermocouple catheter

Electrode supports, two

Combat boots

Rectal temperature was obtained with a copper-constantan thermocouple at a depth of 3 inches. The thermocouple was mounted in a catheter similar to the one described by Davidzick, Harvey, and Goddard.[10] It remained in place without any additional support. Copper-constantan thermocouples made of 22-gage stranded wire were held against the skin with elastic webbing at the front and back of the chest, hip, and above the knee.

* Laundered before each wearing. This underwear was not impregnated, but was approximately equal in heat load to the cotton, special knitted underwear made protective by impregnation with CC_2.

Minneapolis-Honeywell jacks and plugs with copper and constantan elements were used to connect the subjects' cable with the cable leading to the Leeds & Northrup Speedomax 16 point recorder. A thermocouple also was attached to the outer surface of the head harness of the mask on top of the head.

Electrodes (appendix A) for recording the heart rate were held against the skin with elastic webbing. Two electrodes were mounted one above the other on the chest on separate straps. One of the straps also carried a third electrode off to the side.

The nose cup of the protective mask was connected with a Statham pressure transducer (±0.5 psi) operated with a Sanborn strain gage amplifier. The pressure tracing on the remaining two channels of the Sanborn recorder permitted a count of respiratory frequency and gave notice indirectly of any marked change in mask resistance during the run.

The men were weighed with a sensitivity of ±5 gm at about 75°F sitting on a Buffalo platform scale nude and clothed, before and after the day's work, and clothed after 55 minutes of work. The walk was usually resumed after this weighing, which took 5 minutes. Sweat production was determined from the nude weight loss and heat lost by evaporation from the clothed weight loss.

Metabolic gas exchange was not measured routinely because of the difficulty of connecting the apparatus to the M17 mask without modifying the operation of the hood. However, the men were allowed to wear the M9A1 mask (to which connections are easily made) for the collection of expired air on 3 days at 100°F outside the regular schedule. The expired air was collected in a 600-ℓ Collins chain-compensated spirometer for 10 minutes after 15 or 20 minutes of walking on the level at 2 or 3 mph, and for 5 minutes after 5 minutes of walking at 3 mph up a 12% grade. The spirometer was read every minute; absence of a trend with time indicated that a steady state had been reached. After it was mixed, the expired air was analyzed in a Pauling paramagnetic oxygen meter. Oxygen consumption was estimated from the expired minute volume and the inspired-expired oxygen difference after correction for the vapor pressure of water and reduction to standard conditions. The work rates for the three walk conditions are defined by the oxygen consumption.

The outdoor situation is illustrated in figures 1 and 2. The treadmill was located outside the south end of building 357 with the men about 3 feet from the wall facing away from the sun 6° north of east. The rear man did not shade the front man. The walking surface was 32 inches above the asphalt pavement. Dry-bulb and wet-bulb temperatures were recorded using copper-constantan thermocouples mounted in the shade in an air stream moving at 1,000 linear ft/min. The output of a 10-junction Eppley pyrheliometer was recorded continuously to provide a measure of solar radiation and an indication of the passage of clouds. The elevation of the ground was 17 feet above sea level. A globe thermometer was mounted near the men and read at intervals by inspection or by means of a thermocouple. The air within the globe was stirred by a small electric fan, according to the suggestion of Hellon and Crockford.[11] The externally-mounted fan motor was insulated thermally from the globe. Wind velocity and direction were monitored with a Signal Corps AN-GMQ-12 wind measuring set with the sensing elements at the height of the men on the treadmill. It would have been desirable to measure the radiant exchange between the sky, the ground, and the wall and clothing surface, had a fast radiometer been available.

In the indoor situation, the men were at the same distance from the nearest wall and from the ground as in the outdoor situation. The walls were not heated independently; the variations in temperature of thermocouples at various points around the room are listed in table 1, appendix B.

Air movement indoors was measured 1 day at 85°F with subject F.N.C. on the treadmill by an Alnor thermoanemometer. The sensing element was mounted at the end of a probe 10 inches long. The probe was held in the hand in two vertical positions close to the body so that the sensing element was at the level of either the head or the knee. The opening in the probe for the sensing element was oriented either from front to back or from side to side. Since the flow in the air conditioning system of the room did not vary from one temperature setting to another or vary with cycling at one setting, the readings of air flow in table 2, appendix B are considered representative for the series.

III. RESULTS.

A. Experimental Conditions.

The metabolic rates for the three grades of work were 113, 177, and 348 Cal/sq m/hr of body surface area (table 2). In the outdoor series, the environmental temperature varied from 79° to 91°F; the humidity (vapor pressure of water) varied from 14 to 24 mm Hg. In the indoor series the wet-bulb temperature was regulated to produce a vapor pressure at all three

TABLE 2

OXYGEN CONSUMPTION INDOORS AT 100°F

Subject	Date	Treadmill speed/grade	Minute volume		Caloric output
			Respiratory	Oxygen	
		mph/%	l RTPS	l STPD	Cal/sq m/hr
P	10 Aug	2/0	21.6	0.87	126
R	10 Aug	2/0	16.8	0.68	106
P	10 Aug	3/12	62.0	2.35	341
R	10 Aug	3/12	46.2	1.97	307
P*	11 Aug	3/0	23.5	1.08	157
R*	11 Aug	3/0	20.3	1.10	171
P	11 Aug	3/0	26.8	1.44	209
R	11 Aug	3/0	21.6	1.19	186
P	16 Sept	2/0	20.4	0.80	116
R	16 Sept	2/0	14.7	0.66	103
P	16 Sept	3/0	26.3	1.10	159
R	16 Sept	3/0	21.7	0.97	151
P	16 Sept	3/12	62.3	2.73	396
R	16 Sept	3/12	52.2	2.32	346

* Without pack.

dry-bulb temperatures that would approximate the mean of the outdoor series. Outdoors there was no sustained wind as great as 0.5 mph except for one day, 7 September, when the speed varied from 3 to 9 mph. Variations in environmental conditions during any day were small except for those in cloud cover. A sample of the greatest changes was recorded on 2 September (figure 3). During a clear period in the first hour the highest solar intensity of the series, 1.35 gcal/sq cm/min, was recorded. During the second hour a series of clouds passed over, indicated by fluctuations in the Eppley reading. The air temperature and humidity were little affected, but the black globe thermometer flunctuated widely. The head temperatures reflected these

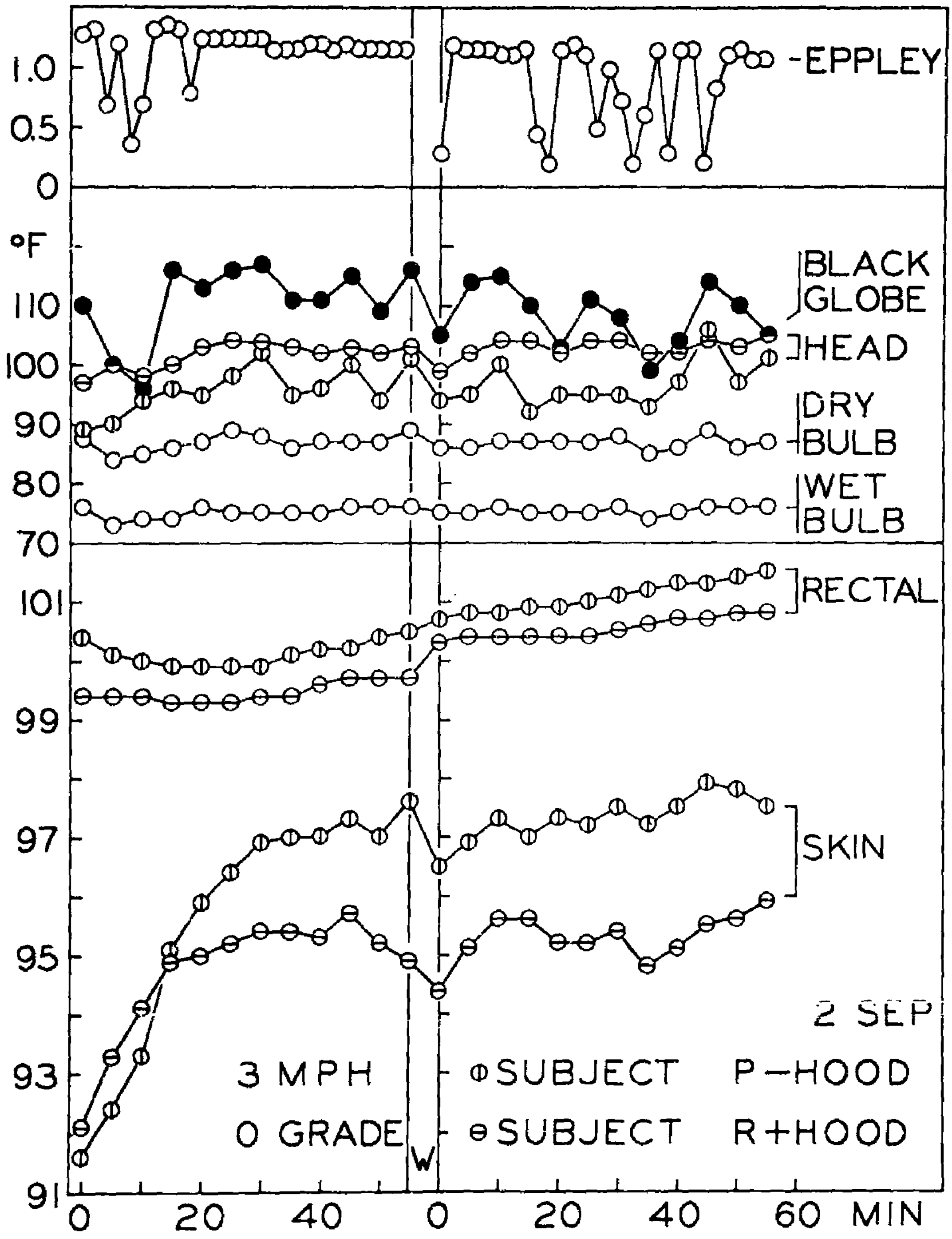

FIGURE 3

GRAPH SHOWING TEMPERATURE AND SOLAR INTENSITIES RECORDED IN OUTDOOR SITUATION ON 2 SEPTEMBER

Subjects P, without hood, and R, with hood, walked on the level at 3 mph. Top line is solar intensity in gcal/sq cm/min as read on the Eppley pyrheliometer; records below are temperatures in °F. Walk was interrupted for weighing indoors for 5 minutes at W.

fluctuations, the more so in the subject not wearing the hood. The mean skin temperatures may have been influenced at times, but the correlation is less obvious. The rectal temperatures appeared to be unaffected. Differences between the helmets mentioned in section II appeared to have no effect on the head temperatures. Details of the environmental conditions are given in table 3, appendix B.

B. Heart Rate.

For examination of the heart rate, the mean of the readings at 5-minute intervals was chosen. The grade of work increased the mean heart rate from 107 at the lowest to 175 at the highest; the change in indoor temperature from 85° to 115°F produced an increase of 24 beats per minute at 2 mph and 23 beats per minute at3 mph on the level. In contrast to these changes, there was an average increase of only 4 beats per minute because of the hood. There was an increase of 17 beats per minute from the first to the second walk outside at 3 mph. At 3 mph and 12% grade, the effect of indoor temperature was small. The mean heart rate was no greater outdoors than it was inside at 85°F. Detailed data are given in table 4, appendix B.

C. Body Weight.

Outdoors the hood had the effect of adding about 200 gm to the sweat production as measured by the nude weight loss. The indoor data do not lend themselves to such a categorical statement because many of the walks were not completed. Detailed weight data, together with reasons given by the men for stopping early, are given in table 5, appendix B. The latter were mostly related to breathing; indications of muscular fatigue in the legs were given in three of the grade walks.

In the level walks outdoors, evaporation through the clothing assembly measured by clothed weight loss was reduced by wearing the hood, by an average of 35 gm for the 2-mph walk and 92 gm for the 3-mph walk. The gain in weight of the clothing due to unevaporated sweat was increased when wearing the hood by about 300 gm.

D. Body Temperatures.

The body temperatures are summarized in table 6, appendix B. The skin temperature is the unweighted average of the thermocouples on the chest, back, hip, and knee. The data for the thermocouple on the head harness are listed with the environmental conditions (table 3, appendix B). The means for skin and rectal temperatures were derived from observations at 5-minute intervals except in the second walk at 3 mph on the level (3/0), when they were derived from readings at 0, 5, 15, 30, 45, and 55 minutes. Mean body temperature was calculated for each time of observation from the skin and rectal temperatures, weighted one third and two thirds, respectively. In a typical outdoor experiment, figure 3, the variations in environmental conditions during a test were reflected to some extent in the body temperature measurements. The data for both men (with and without hoods) were pooled in figures 4 and 5 to simplify comparison of the indoor temperature and exercise conditions. During the first 15 or 20 minutes, the skin temperature rose rapidly while the rectal temperature changed little or decreased 1 or 2 tenths of a degree. After this the body temperatures increased at a more or less steady rate in the level walks; an interruption was provided by the weighing period. For reasons discussed below, the rise in mean body temperature was selected as the best index of the physiological effect of the experimental conditions of clothing and environment. From the plots of mean body temperature against time for individual tests, the best slopes were fitted by eye; the first 15 minutes of the level walks were ignored. In the first level walks the hood produced an increase in slope ranging from 0.16° to 0.55°F per hour with a mean of 0.36°F.

In view of Gosselin's results,[9] a linear relation was assumed between the air temperature (x = motor psychrometer dry-bulb temperature in table 3, appendix B) and rise in mean body temperature (y) in table 3, appendix B. The least squares relation was calculated from the data for each man without regard to the hood (N, number of observations, = 6). The slopes defined by the equation

$$y - \bar{y} = b\,(x - \bar{x})$$

with 95% confidence limits, are listed in table 3. The square of the coefficient of correlation (r) represents the variance caused by x. From these equations is calculated the temperature required to produce the same rise in mean body temperature as was obtained outdoors at the mean outdoor dry-bulb temperature in table 4. The difference between these indoor and outdoor temperatures represents the thermal stress of sunshine and has an average value of 9.5°F for the four conditions indicated in table 3.

The ranges of day-to-day variation in outdoor environmental conditions were 12°F in dry-bulb temperature, 10 mm Hg in water-vapor pressure, and 0.68 cal/sq cm/min in solar intensity read on the pyrheliometer.

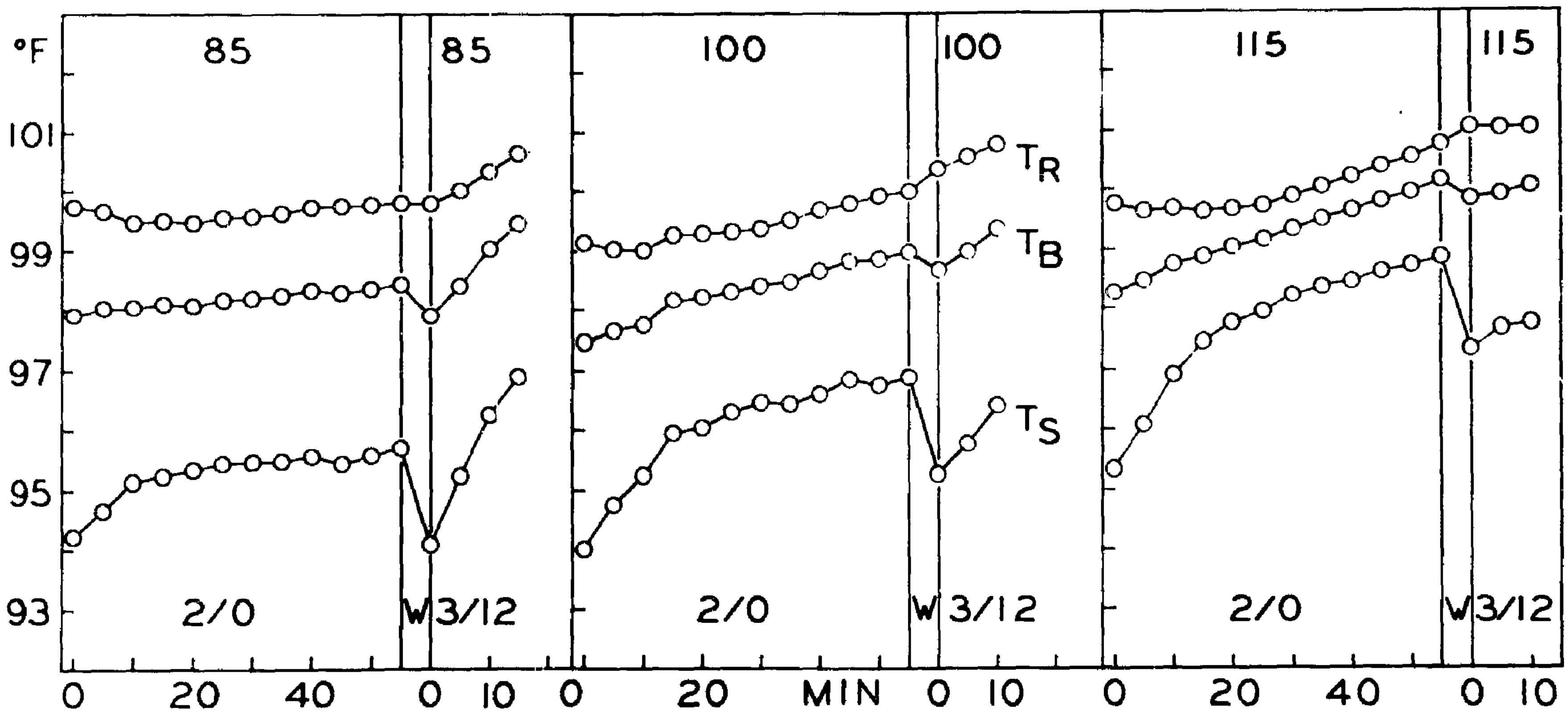

FIGURE 4

GRAPH OF INDOOR RECTAL, MEAN, BODY, AND SKIN TEMPERATURES
FROM POOLED DATA ON TWO SUBJECTS WITH AND WITHOUT HOOD

Room temperature indicated at top; treadmill speed and grade indicated as ratio at bottom. Walk was 2 mph on level and 3 mph on 12% grade; W=5-minute break outside hot room for weighing

T_S=mean skin temperature
T_B=mean body temperature
T_R=rectal temperature

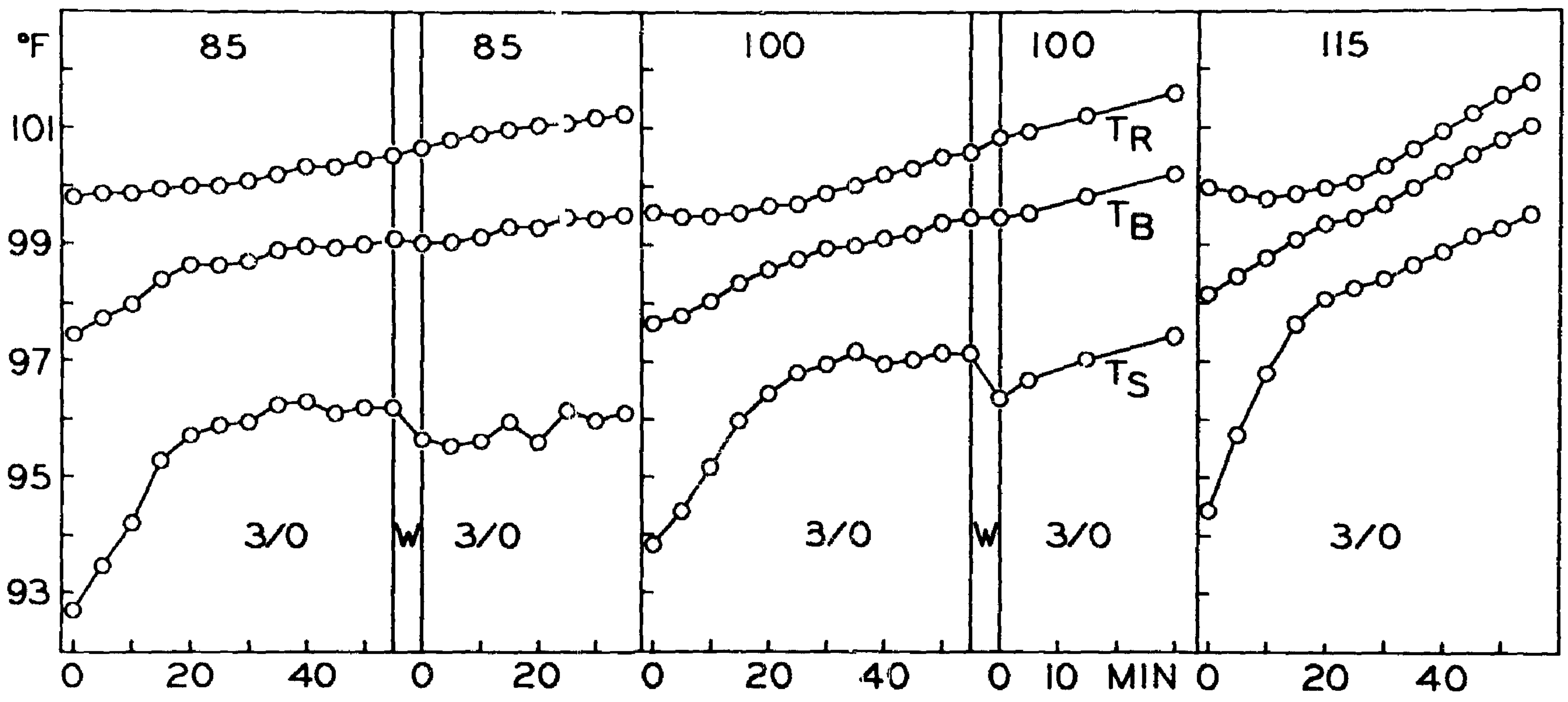

FIGURE 5

GRAPH OF INDOOR RECTAL, MEAN BOD' AND SKIN TEMPERATURES FROM POOLED DATA ON TWO SUBJECTS WITH AND WITHOUT HOOD

Room temperature indicated at top; treadmill speed and grade indicated as ratio at bottom. Walk was 3 mph on level; W=5-minute break outside hot room for weighing

T_S =mean skin temperature
T_B=mean body temperature
T_R= rectal temperature

TABLE 3

CALCULATION OF THERMAL STRESS OF SUNSHINE AS INCREMENT IN DRY-BULB TEMPERATURE

Measurement	Treadmill speed (level)			
	2 mph		3 mph	
	Subject R	Subject P	Subject R	Subject P
No. of observations*	6	6	8	8
Mean dry-bulb temp indoors, °F ($=\bar{x}$)	100.0	100.0	103.8	103.8
Mean rise in body temp indoors, °F/hr ($=\bar{y}$)	0.89	1.49	2.15	2.52
Slope	0.056	0.045	0.083	0.085
95% confidence limits of slope	±0.012	±0.011	±0.014	±0.012
r^2 (variance due to x)	0.85	0.79	0.79	0.85
Mean dry-bulb temp outdoors, °F	83.0	83.0	85.8	85.8
Mean rise in body temp outdoors, °F/hr	0.54	1.00	1.40	2.03
Equivalent dry-bulb temp indoors, °F	93.8	89.0	94.9	98.0
Solar increment, °F**	10.8	6.0	9.1	12.2

* Data pooled from tests with and without hood.
** Environmental temperature increase required to produce equivalent physiological stress without sunshine.

TABLE 4

SKIN AND CLOTHING TEMPERATURES AVERAGED OVER 1 HOUR OF WALKING

(Room temp, 85°F; humidity, 20 mm Hg; readings made at 5-minute intervals; tests performed on 25 and 26 April; subject, F.N.C.)

Location	Average temperatures							
	Speed, 2 mph; nude wt loss, 0.29 kg; clothing wt gain, 0.13 kg				Speed, 3 mph; nude wt loss, 0.66 kg; clothing wt gain, 0.37 kg			
	Skin	Undershirt		Jacket outside	Skin	Undershirt		Jacket outside
		Inside	Outside			Inside	Outside	
	°F							
Chest	95.9	93.3	94.2	89.0	95.9	94.2	93.9	90.7
Shoulder	95.1	93.6	94.3	90.1	93.9	93.0	93.6	90.2
Hip	95.6	95.6	95.7	89.7*	94.9	96.2	94.8	94.9*
Arm	94.1	92.3	93.0	93.1	95.3	92.4	93.3	89.2
Average	95.2	93.7	94.3	90.5	95.0	94.0	93.9	91.3

* Jacket tucked inside trousers at this location.

When the slope of mean body temperature in the outdoor tests was plotted against any one of these variables, there was little correlation on inspection. The coefficient of correlation between rise in mean body temperature and dry-bulb temperature was calculated for R and P at 2 and 3 mph. The values of r were 0.29, 0.58, 0.62, and 0.70, respectively. Accordingly, day-to-day physiological variation was not distinguishable from the variation produced by the environmental conditions. Fortunately, in the 2-mph walks, outdoor temperatures varied little between days with hood and days without hood. The effect of the hood was evident in the means for each subject. In the 3-mph level walks (table 3, appendix B) one set of days was warmer and more humid than the other, with the result that the effect of the hood on the rise in mean body temperature was exaggerated in subject R and nullified in subject P. In subject P, the cooler days with the hood produced the same average slope as the warmer days without the hood. This in itself indicates that the hood in this instance had about the same effect as a 4°F increase in dry-bulb temperature combined with an increase in vapor pressure of 3 mm Hg.

E. Walking Time.

The duration of the walk (table 5, appendix B) is a subjective measure of the total stress. Outdoors, all of the first 55-minute walks were completed. Of the grade walks, P failed to complete one with and one without the hood, and R failed to complete two walks with the hood; of the second-level walks, P failed to complete two without the hood and one with the hood, and R failed to complete two with the hood. Outdoors, therefore, the effect of the hood was not distinct. Indoors, each subject walked about three fourths as long with the hood up the 12% grade at all temperature conditions, and the average time decreased with an increase in the temperature. At 3 mph on the level, both subjects failed to complete the second walk with hood at 85° and 100°F, and at 115°F, P failed to complete the first walks and walked a shorter time with than without the hood. The notes in table 5, appendix B suggest that P was weakened by a head cold at 115°F that made breathing a problem and at 85°F, the final condition in the sequence, the men were suffering from an accumulation of difficulties not related to the hood. The indoor grade walks, therefore, give a better indication of the degradation of performance by the hood than the indoor level walks. Since the rise in body temperature (table 3, appendix B) was less in the grade walks with than without the hood, we must look elsewhere for an explanation. An obvious possibility is expiratory pressure; the test on this factor (given below) showed that elimination of extra expiratory pressure from the hood did not improve performance. Also, there is no explanation for the appearance of a degradation of performance indoors unless perhaps the passage of time decreased motivation indoors.

F. Hood Pressurization.

Two days at 115°F, 29 and 30 September, were devoted to a comparison of the effects of the pressurized and the unpressurized hood (tables 3-6, appendix B). The hood is pressurized during expiration in the sense that the expired air is normally vented into it; when the outlet of the mask is not covered by the hood, the hood is unpressurized. The head of pressure has not been standardized because it is set by the wearer when he tightens the draw-string around the neck. In the present tests, the uncovering of the outlet valve did not improve performance in the grade walks and did not alter the physiological data significantly. During the level walks at 2 mph, pressurization increased the frequency of breathing, decreased the pressure during inspiration, and increased the pressure during expiration, all by small amounts (table 5).

G. Clothing Temperatures.

In the analysis of the data on evaporation through the clothing, information was desired on the temperatures of the various layers of the assembly. Two additional tests were made with another subject, F. N. C., walking on the level indoors at 115°F with a vapor pressure of 21 mm Hg. The clothing itemized in list 1 was worn except for the headgear and pack. Thermocouples were applied to the skin in the same positions as in the main series of tests on the front and back of the chest and the hip, but for convenience the fourth was applied to the upper arm instead of the knee. Three sets of thermocouples were sewn into the clothing immediately over those on the skin. On 7 December, the treadmill speed was 2 mph and the extra thermocouples were located on the outer side of the underwear and the inside and outside of the jacket. On 9 December, the treadmill speed was 3 mph and the extra thermocouples were located on the inside and outside of the underwear and the outside of the jacket. Extra layers of clothing covered the thermocouples in the hip position. The undershirt was tucked into the drawers and the jacket was tucked into the trousers. The clothed weight loss, nude weight loss, and gain in weight of clothing were 371, 790, and 419 gm, respectively, on 7 December and 388, 1,136, and 748 gm, respectively, on 9 December. On 9 December, the gain in weight of the jacket was 81 gm and that of the undershirt was 301 gm; this indicates that the unevaporated sweat was mainly in the underwear layer. The temperatures of selected locations are plotted in figure 6. Within 20 to 30 minutes, the temperature of the undershirt had fallen below that of the skin. The greatest difference was more than 3°F. Similar observations were made at 85°F (table 4).

TABLE 5

COMPARISON OF RESPIRATORY EFFECTS OF PRESSURIZED (+P) AND UNPRESSURIZED (-P) HOODS

(Tests performed on 29 and 30 September at 115°F and 2 mph)

Subject	Time	Respiration rate		Peak pressure			
				Inspiration		Expiration	
		-P	+P	-P	+P	-P	+P
	min	no./min		mm H_2O			
R	6	26.8	26.0	-20.5	-16.2	10.1	13.0
	30	27.0	28.0	-23.1	-23.9	14.6	18.9
	45	25.0	26.6	-26.6	-26.0	14.0	20.8
P	6	22.4	22.4	-36.6	-26.8	14.4	10.4
	30	21.6	23.0	-33.2	-30.9	14.6	18.8
	45	22.0	25.0	-30.8	-32.0	13.5	12.4
Average	—	24.1	25.2	-38.5	-26.0	13.5	15.7

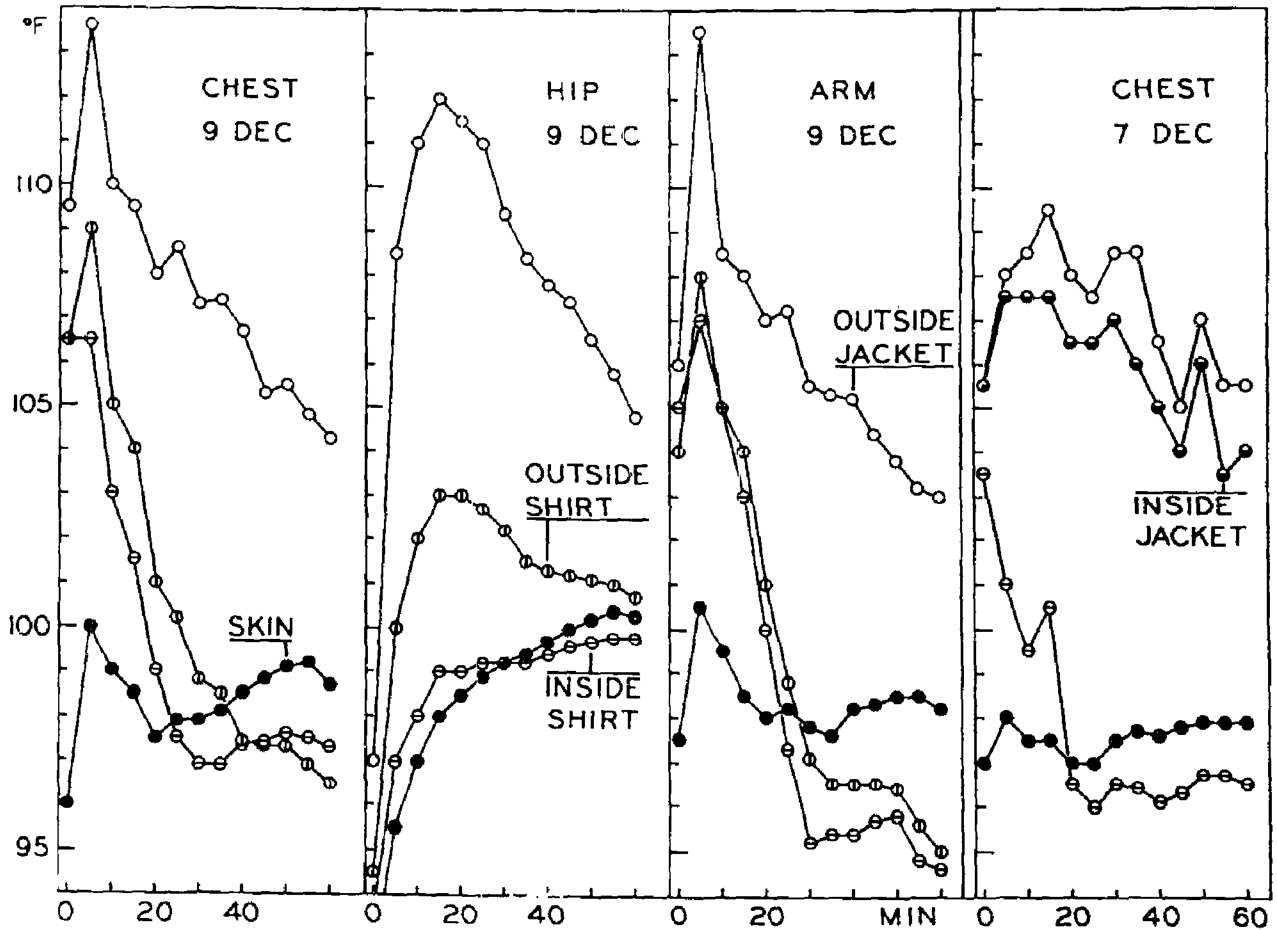

FIGURE 6

GRAPH OF TEMPERATURES OF THERMOCOUPLES AT VARIOUS POSITIONS WITHIN CLOTHING ASSEMBLY

Thermocouples located on skin, inside and outside of undershirt, and inside and outside of jacket for various locations on body of subject F.N. C. at 115°F and vapor pressure of 21 mm Hg. Treadmill speed 2 mph on 7 December and 3 mph on 9 December.

IV. DISCUSSION.

A. Effects of Hood on Performance.

The change in the slope of the plot of body temperature against time was qualitatively the most important objective effect of the hood.* The means with and without the hood include data that overlap so much that statistical analysis is not justified. Accordingly, the experiments are to be considered as range-finding rather than definitive. However, the degree of uniformity among the differences in the means for the various level conditions would appear to give them some validity.

The practical significance of the observed differences may be seen on conversion of the slopes of the curves for mean body temperature as a function of time into rates of heat storage. In previous experiments with protective clothing,[22] the voluntary tolerance time was reached with the storage of a fixed quantity of heat, namely an average of 54 Cal/sq m of body surface for the six men studied.

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* In earlier work in these Laboratories, beginning with Robinson et al.,[12] the stress of heat, clothing, and exercise was measured in terms of a physiological strain index, an empirical combination of changes in heart rate, rectal temperature, and sweat production. The index was modified by Craig[13] in 1950 and again in 1952 by Craig, Frankel, and Blevins.[14] However, it became apparent that an index with some relation to the experimental conditions would be more useful. As pointed out by Craig et al.[15] and independently by Blockley et al.,[16] the rate of heat storage fulfilled this requirement and voluntary tolerance time was inversely proportional to the rate of heat storage. The rate of heat storage is correlated closely with the triple index, as Craig et al. found.[15,17,18] Recently, more extensive evidence of this has come from another laboratory.[19] A refinement of the computation of the rate of heat storage originated with Drupieski and Woodward,[20] who pointed out that instead of basing the rate on initial and final temperatures alone, the slope should be used and the data for the first few minutes, often highly variable, should be disregarded. This practice has also been adopted by Gold.[21]

For any rate of heat storage the voluntary tolerance time may be estimated by dividing this constant by the rate. Estimates derived from the outdoor data are given in table 6. Although wearing the hood increased the heat storage by about the same amount at both speeds of walking on the level, it decreased the calculated tolerance time by 17 minutes for the 3-mph walk and 104 minutes for the 2-mph walk. In the grade walks the rate of heat storage was so great that the difference due to the hood would be inconsequential. Also, heat storage was not the limiting factor here, since excessively high body temperatures were not reached. Whether the rates of heat storage observed in the first hour at 2 mph would remain the same in later hours cannot be predicted. At 3 mph on the level, the rate of heat storage was well maintained in the second hour. If the heat stress is moderate, the progressive wetting of the clothing with sweat may increase the evaporative loss so that the heat storage will eventually decline. Illustrative data have been published,[22] and the changes in heat storage in the second hour will be discussed below.

TABLE 6

EFFECT OF HOOD IN TERMS OF VOLUNTARY TOLERANCE TIME UNDER CONDITIONS OF OUTDOOR TESTS

Treadmill speed/grade	Hood	Heat storage	Calcd voluntary tolerance time
mph/%		Cal/sq m/hr	min
2/0	-	11	295
2/0	+	17	191
3/0	-	29	112
3/0	+	34	95

B. Comparison With Underwear.

It would have been desirable to measure the heat stress on the soldier wearing the ordinary combat uniform as a control in the present tests, but because of the need for early results on the hood, this was not done.

Data obtained earlier[7, 15, 18] and listed in table 7 are not strictly comparable because of the differences in subjects and in the clothing assemblies. Changing from short to long underwear in well-acclimatized subjects[18] doubled the strain (heat storage) at small rates of heat storage. The effect was even greater in poorly-acclimated subjects[7]; here the metabolic rate was as great as in the present tests in which a pack was carried, and the rate of heat storage because of the long underwear was 20 Cal more. Over a 2-hour period, the increase in storage was 86% as a result of the long underwear[18] and 35% because of the E33 hood; the absolute increase was less with the long underwear than the hood. The first comparison in table 7 is between short underwear without a hood and long underwear with a permeable E26 hood; here the increase in heat strain was 111% or somewhat less than the sum of 85 and 35%. Since the number of men and observations were only two in each of the comparisons, and the men varied between themselves, these figures can be taken as only very general approximations.

In the present studies the rates of heat storage in the first hour were continued into the second hour with little change, as is seen in table 7. for 100°F. In table 8 results for the other walks at 3 mph on the level under various temperatures are given; the second-hour rates increased over the first-hour rates. At 85°F both indoors and outdoors, however, the difference due to the hood was less in the second hour. It is unlikely that the subjects tested previously[7] would have been able to complete the second hour.

C. Analysis of Heat Exchange.

The source of the difference in heat storage due to the hood will appear in the analysis in table 8. The rate of heat storage (S) is related to the other factors in the situation according to the equation:

$$S = M - W - H - E \qquad (1)$$

where

M = heat produced in metabolism (table 3)

W = external work (from lifting the body in grade walking, 0.575 km/hr)

H = sensible heat loss by radiation, convection, and conduction

E = insensible heat loss by evaporation (the total heat required to evaporate in water measured by the clothed weight loss in

TABLE 7

COMPARISON OF SEPARATE EFFECTS OF HOOD AND LONG UNDERWEAR ON HEAT STORAGE OF MEN

(Walking indoors at 3 mph on level treadmill at 100°F)

Reference	Marginal clothing*				Time	Metabolism	Heat storage
	Hood	Long under-wear	Short under-wear	Pack			
					hr	Cal/sq m/hr	
15	-	-	+	-	2	143	9
15	+	+	-	-	2	160	19
18	+	-	+	-	2	148	7
18	+	+	-	-	2	158	13
7	+	-	+	-	1	179	22
7	+	+	-	-	1	179	52
Present work	-	+	-	+	1	177	22
Present work	+	+	-	+	1	177	32
Present work	-	+	-	+	2	177	23
Present work	+	+	-	+	2	177	31

* All wore combat boots and cushion socks. In previous studies[15, 18], the jacket and trousers were herringbone twill, the mask was the M9, and the hood was permeable. In the work of Woodward and Cummings[7] and the present work, the jacket and trousers were sateen, the mask was the M17, and the hood was made of impermeable cloth.

TABLE 8

EFFECT OF HOOD ON EVAPORATION

Sun	Treadmill	No. of obsn ± hood	Ta[a/]	Ts[b/]		E[c/]		Ps-Pa[d/]		Cp[e/]		Decrement in Cp due to hood	S[f/]	
	Speed/grade		± Hood	- Hood	+ Hood	- Hood	+ Hood	- Hood	+ Hood	- Hood	+ Hood		- Hood	+ Hood
	mph/%			oF		Cal/sq m/hr		mm Hg				%	Cal/sq m/hr	
						First walk								
+	2/0	8	83.0	94.1	94.6	146	135	21.2	21.9	7.1	6.2	13	11	17
-	2/0	4	85.4	95.1	95.5	93	84	21.8	22.6	4.3	3.7	14	4	10
-	2/0	4	99.2	96.1	96.0	111	99	22.6	22.5	4.9	4.4	10	19	29
-	2/0	4	115.5	97.9	98.1	126	147	26.1	26.3	4.9	5.6	-14	31	39
+	3/0	8	85.8	95.7	95.9	182	153	21.2	21.8	8.6	7.2	16	29	34
-	3/0	4	84.8	95.6	95.2	109	103	22.2	21.6	4.9	4.5	8	15	22
-	3/0	4	100.3	95.8	96.7	163	187	20.8	21.3	7.9	8.5	-8	22	32
-	3/0	8	115.0	97.8	97.7	217	214	25.3	25.3	8.7	8.4	3	61	64
						Second walk								
+	3/0	8	85.8	95.8	96.3	235	238	21.6	22.2	11.0	11.0	0	17	19
-	3/0	4	84.8	96.1	95.8	163	146	22.9	22.4	7.2	6.5	10	15	13
-	3/0	4	100.3	96.6	97.4	211	206	22.0	23.0	9.7	9.0	7	23	29
+	3/12	8	83.0	94.9	95.5	246	303	22.3	23.3	11.8	13.1	-11	112	104
-	3/12	4	85.4	95.3	95.6	204	253	21.5	22.7	9.4	10.7	-14	109	107
-	3/12	4	99.2	96.0	95.5	280	533	22.2	21.8	12.3	26.7	-117	82	71
-	3/12	4	115.5	97.2	97.6	366	594	25.2	25.7	14.5	23.1	-59	33	22

a/ Ta = Environmental air temperature.
b/ Ts = Average skin temperature during walk.
c/ E = Heat loss by evaporation.
d/ Ps - Pa = Difference in vapor pressure between skin and air.
e/ Cp = Conductance of clothing for water vapor as defined in text.
f/ S = Heat stored in body.

table 5, appendix B, less the heat of evaporation of water lost from the lungs. This amounted to 5, 7, and 14 Cal/sq m/hr for the 2/0, 3/0, and 3/12 conditions, respectively)

All of these quantities have the dimensions of Calories per square meter of body surface per hour. H was not measured directly but was obtained from equation (1). If all evaporation took place at the skin and not in the clothing, H could also be calculated as follows:

$$H = 3.09\ (Ts - Ta)/(Ia + Ic) \tag{2}$$

where

Ta = air temperature (dry bulb in table 1, appendix B; ideally with still-air and wall temperatures equal to Ta)

Ts = mean skin temperature from table 6, appendix B. For a rigorous analysis, conditions should be chosen that will allow Ts to remain constant; here Ts varied (figures 3 to 5)

Ia = insulation of the air in clo units, where 1 clo is defined as the insulation required to maintain a difference of 0.324°F between Ts and Ta with the transfer of 1 Cal/sq m/hr[23]; 3.09 = 1/0.324°F

Ic = insulation of the clothing in clo units

E was given by the clothed weight loss, the specific heat of water (0.58), and the weight and surface area of the subject (table 1).

Also,

$$E = Cp\ (Ps - Pa) \tag{3}$$

where

Cp = conductance of the clothing for insensible heat. It would be appropriate to express this in terms of grams of water vapor, but energy terms are retained for coherency. Cp also is affected by air movement.

Pa = vapor pressure of the air (table 3, appendix B)

Ps = vapor pressure of the skin, assumed to be saturated at Ts, with the skin completely wet.

The evaluation of the insulation of clothing becomes more complicated when evaporation takes place in the clothing. Burton[24] and Burton and Edholm[25] have treated the case of clothing in which the underwear is dry and sweat accumulates in outer layers of clothing. In our assembly the underwear wetted out and the outer layer remained dry over most areas. The approach of Burton, therefore, is modified below. Although conditions were changing during the walks, we can deal only with average states, so that the analysis at best can be only a rough approximation. When Ta is greater than Ts, H is negative and the heat of evaporation, E, measured by the clothed weight loss is contributed partly by the body and partly by the environment. Evaporation is regarded as taking place at the outer surface of a wet layer next to the skin with insulation Iw. This is also the inner surface of a dry layer with insulation Id. The insulation of the clothing assembly is the sum of Iw and Id. The insulation of the air layer outside the clothing is Ia. The temperature at the evaporating surface is T. The heat of evaporation furnished by the body, E + H, is equal to M - S - W and moves to the site of evaporation over the gradient Ts - T. The heat of evaporation furnished by the environment, H, is equal to M - W - S - E and moves to the site of evaporation over the gradient T - Ta. As defined, H is negative when T is less than Ta. For values of T in degrees Fahrenheit the constant 3.09 is applied to relate T with E in Cal/sq m/hr and I in clo units. Then:

$$3.09\,(T - Ta) = H\,(Ia + Id) \tag{4}$$

$$3.09\,(Ts - T) = (E + H)\,Iw \tag{5}$$

A clue to the value of T was provided by the readings of thermocouples attached to the inside and outside of the undershirt worn by F.N.C. at 115°F after the conclusion of the tests on subjects R and P. According to the data in figure 6, T (as indicated by the underwear temperatures) fell one or two degrees below Ts. Similar observations were made at 85°F. Here the changes with time were small and temperatures at four locations on the body were averaged in table 4 to show the differences between the skin and clothing. The observations are less crucial because the same sort of gradation would be expected for both wet and dry clothing.

For the sake of illustration and guided by the above observations, we assumed that in subjects P and R, the temperature of the evaporating layer T was always 1°F less than Ts. It was then possible to calculate the insulation of the wet and dry layers according to equations (2), (4), and (5) (table 9). As would be expected from these equations, the size of the

TABLE 9

HEAT BALANCE AND INSULATION IN FIRST LEVEL WALKS

Sun	Temperature, °F		Stored Heat, S	Heat Evapn, E	Sensible Heat loss, H	Estimates of insulation*		
						Assumption 1		Assumption 2
	Air, Ta	Skin, Ta				Iw clo	Ia + Id + Iw clo	Ia + Ic clo
	Treadmill speed, 2 mph; metabolic rate, M = 113 Cal/sq m/hr							
+	83.0	93.6	14	141	-42	0.031	- 0.67	-0.78
+	103.0**	93.6	14	141	-42	0.031	0.80	0.69
-	85.4	94.3	7	88	18	0.029	1.31	1.53
-	99.2	96.0	24	105	-16	0.035	0.85	0.62
-	115.5	98.0	35	136	-58	0.040	1.02	0.93
	Treadmill speed, 3 mph; metabolic rate, M = 177 Cal/sq m/hr							
+	85.8	96.1	31	167	-21	0.021	-1.35	-1.51
+	98.8**	96.1	31	167	-21	0.021	0.56	0.50
-	84.8	95.4	18	106	53	0.019	0.58	0.62
-	100.3	97.3	27	175	-25	0.021	0.52	0.37
-	115.1	97.7	62	215	-100	0.027	0.59	0.54

* Assumption 1: all evaporation from wet underwear: T = Ta - 1; equations (4, 5).
Assumption 2: dry clothing, equation (2).

** Ta increased arbitrarily to bring outdoor insulation within range of indoor insulation.

difference between Ia + Ic and Ia + Id + Iw depends upon how great a fraction of Ts - Ta the difference between T and Ts is. The direction of the difference depends on whether Ts is greater or less than Ta. When Ta is greater than Ts, T - Ta is greater than Ts - Ta. From equations (2), (4), and (5), an expression is obtained that defines the relation between Ic and Id + Iw:

$$Ic = Id + Iw + E/H\ Iw \qquad (6)$$

At 85°F the effect of sunshine on the heat balance was to convert sensible heat loss to heat gain and hence to increase the requirements for heat loss by evaporation. The outdoor condition presents an interesting problem in the calculation of insulation. The values for Ia + Ic obtained in table 9 from equation (2) are negative since Ts - Ta is positive and H is negative. To obtain insulations comparable with those estimated for the indoor condition, it was necessary to add 20°F at 2 mph and 13°F at 3 mph to the outdoor air temperature. Since these additions are greater than the thermal increment for sunshine developed from the physiological strain, it is clear that adding 10°F to the indoor air temperature does not duplicate all the effects of sunshine. More detailed study of the effect of sunshine on clothing insulation is required. Some information is available concerning the exchange of radiant energy between men wearing protective clothing and a desert environment.[26]

The striking feature of this analysis is the great lability we must attribute to the thermal insulation of this clothing assembly under the influence of environmental temperature and activity. A similar decrease in insulation with increase in walking speed has been demonstrated for arctic clothing.[27] The extention of the analysis to include the relatively small changes attributable to the hood did not seem worthwhile. Consideration of the clothed weight loss alone, however, is enough to account for the facts that heat storage was similar at 2 and 3 mph at 100°F on the level and decreased with environmental temperatures in the grade walks. It seems likely that if the grade walks had been continued, the thermal exchanges would have rearranged themselves so that heat storage was greater at the higher environmental temperatures.

Comparison of the indoor and outdoor first walks show that the greater evaporation outdoors than indoors did not prevent the heat storage also from being greater outdoors than indoors. The indications from the thermal analysis are that a greater share of the heat of evaporation came from the environment in the outdoor walks. In the second walks the evaporation outdoors was perhaps sufficiently greater than in the first walks to diminish the difference between heat storage indoors and outdoors. It should be noted in the level walks at 3 mph that, whereas, indoors S remained nearly the same from the first to the second walk at both 85° and 100°F, outdoors S declined in the second walk. In both cases E increased from the first to the second walk. Since we cannot explain in detail the apparent inconsistencies in behavior between S and E, we are free to attribute them to changes in insulation. Therefore, some caution must be observed in any attempt to extrapolate these results to longer periods of walking.

Having seen the general outline of the thermal exchanges, we may return to the effects of the hood on heat storage and ask whether they can be attributed to differences in evaporation. The conductance of the assembly for evaporative heat loss, Cp, has been defined above as the ratio of the rate of evaporative heat loss to the vapor pressure gradient for the surface area of 1 sq m. Since the impermeable hood reduces the surface area available for evaporation, a reduction in Cp in proportion to the change in area was to be expected. The area of the neck and shoulders covered by the hood is estimated to be about 2 sq ft (0.18 sq m) or about one tenth of the surface area of the body.* The values of Cp with and without the hood are listed in table 8, together with the averages of the data from which they were calculated. F nine out of 11 level walking conditions, the increase in heat storage with the hood was matched by a decrease in evaporative heat loss; for the 11 conditions, the average increments were 4 Cal for E and 6 Cal for S, and the average decrement in Cp was 5%. These averages include large variations in data for individual tests, as may be seen in table 5, appendix B. The variations may arise from sweat that dripped off instead of being evaporated. Also the weight change represents a single measurement for the whole walking period, whereas the storage figure omits the first 15 minutes. The hood appeared to have little effect on the vapor pressure gradient.

In the brief grade walks, the hood decreased storage and increased evaporation and Cp. A possible explanation here is that the clothing retained more sweat at the end of the level walks with than without the hood; this would

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* The skirt of the hood worn over the shoulders is about 36 inches in circumference and 6 inches in width (216 sq in.) and the neck accounts for another 60 sq in. For comparison, the area of the lower arms and legs covered by outer clothing only and not by underwear in the tests of Woodward and Cummings[7] amounted to 36% of the total surface area. The estimate is based on figures of Lund and Browder.[28]

favor more rapid evaporation during the short grade walks with than without the hood. The same explanation is advanced to account for the decrease in storage with increased ambient temperature in the grade walks. In summary, the data tend to support the hypothesis that the effect of the hood depends on the surface covered, but are not good enough to establish it conclusively.

D. Solar Radiation.

At the same environmental temperature, the physiological strain is greater in the sunshine than in the shade, at night, or indoors. The increase in temperature of the latter environments required to produce the same physiological strain observed in the sunshine may be defined as the solar increment. By pooling the data for the level walks at both 2 and 3 mph (table 3), one can arrive at a mean solar increment of $10 \pm 4^{\circ}F$ based on the slopes of the rise in mean body temperature and a mean solar intensity of 79% of the intensity for a cloudless day. Since the subjects differed, there is no clear evidence that the solar increment was affected by walking speed. The only other estimates of the solar effect derived from the physiological responses of men were made by Adolph and Molnar[8] and Gosselin.[9] The subjects of Adolph and Molnar were lying at rest almost nude at temperatures below 85°F, and the comparison was made between sunshine and shade in the same position outdoors. In contrast, the subjects in this report were walking clothed and erect and the comparison was made between outdoor and indoor conditions. For the following indexes of physiological strain, the solar increments were 10°F for heat storage, 9°F for sensible heat loss, 11°F for evaporative heat loss, 13°F for mean skin temperature, and 13°F for the mean skin temperature, and 13°F for the threshhold of shivering. One increment was reported for work on a bicycle ergometer at a mean heat production of 221 Cal/sq m/hr, namely 11°F for evaporative heat loss.

The subjects of Gosselin[9] were wearing herringbone twill fatigue suits and walking at about 3 mph in the desert at night and in the sunshine. The environmental temperatures in each condition ranged from 90° to 110°F, and the index of physiological strain was the rate of sweating. This measure is technically superior in desert than in humid conditions used here, because there is no unevaporated sweat to be lost by dripping. Gosselin concluded that direct sunlight is responsible for an elevation in rate of sweating roughly equivalent to that produced by a rise in air temperature of 10°F.

It appears that the environmental conditions in the hot room at 115°F were as severe as those experienced in the JACKPOT tests in Alabama.[6] For the purpose of measuring the effects of small changes in insulation resulting from the addition of a hood to an assembly already well insulated, the results show that the more severe conditions are less favorable than milder conditions. Accordingly, fears that the earlier work[5] may have failed to reveal a large effect of the hood because only moderate conditions were employed have proved to be groundless. In view of the available information (section B, above) we are inclined to attribute a larger share of the effects noted in Alabama to the underwear than to the hood.

E. Military Applications.

At least since the battle of Marathon, troop commanders have been aware that a man can run himself to death, or more commonly, to heat exhaustion. Sensitivity to the physical capacities of his men has always been the mark of a successful commander. The methods of conserving this limited resources are implicit in the relationships stated in section C on the analysis of heat exchange. However, one does not need to be a physiologist to appreciate the effectiveness of avoiding direct sunlight, reducing the marching speed or the weight of the pack, adding rest periods, discarding unnecessary layers of clothing, and maintaining fluid intake. The quantitative application to specific situations is beyond the scope of this report. The problem is made more difficult when CBR protective equipment is worn because the commander is deprived of many of the cues he normally depends on to evaluate the physical condition of his men, such as the facial expression and the appearance of the skin. Accordingly, we wish to endorse the recommendations of the JACKPOT report[6] to make adjustments of the pace of the work appropriate to the conditions of environmental temperature and humidity when protective clothing is worn. The data in tables 6 and 7 concerning the hood and the underwear are for the purpose of illustration and are not offered as a guidance in any specific situation.

V. CONCLUSIONS.

The E33 hood adds measurably to the heat stress of the CBR protective assembly. The added stress at an environmental temperature of 85°F is about two thirds that of sunshine and about one half that of an increase in the marching speed from 2 to 3 mph.

The hood does not interfere with the performance of muscular work of moderate intensity. In the hardest work, the voluntary tolerance time is decreased about one fourth.

The heat strain in men working in CBR protective clothing at a given temperature outdoors in the sun can be duplicated indoors at a room temperature 10°F higher than the outdoor temperature.

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APPENDIXES

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APPENDIX A

BLEVINS ELECTRODE

The electrodes (figures 1 and 2) were designed by W. V. Blevins and represent a departure from earlier practice in this Laboratory. The essential feature of the electrode is the salt bridge, used in connection with exercising men as long ago as 1910 by Buchanan,[1] who placed each hand in a basin of salt water. The electrode of Smith[2] consisted of a brass disk imbedded in electrode paste held against the skin with a rubber cover; the disk was not prevented from coming into direct contact with the skin. Efforts to improve the signal by attaching a metal electrode more firmly to the skin were not successful in this Laboratory.[3 (and 7, text)] In 1959 contact of metal with the skin was eliminated with the electrodes of Rowley, Glagov and Stoner[4] and of Rosenblat and Dombrovskii.[5] One drawback of this electrode was the necessity for attaching the nonconductive cup that held the electrode paste very firmly to the skin; this was a time-consuming process and irritating to the skin in repeated daily applications. In the Blevins electrode a plastic cup 1 inch in diameter contains a wad of absorbent cotton impregnated with electrode paste that maintains contact between the skin and the copper lead wire. The cup is held against the skin with a strap of elastic webbing. It is surrounded by a disk of plastic about 2 1/2 inches in diameter to prevent the cup from turning over. The electrode is free to slide about over the surface of the skin without impairing the distinctness of the QRS wave over a 2-hour period. The baseline may fluctuate by a few millivolts, but it remains on scale without adjustment of the recorder (Sanborn four-channel oscillograph).

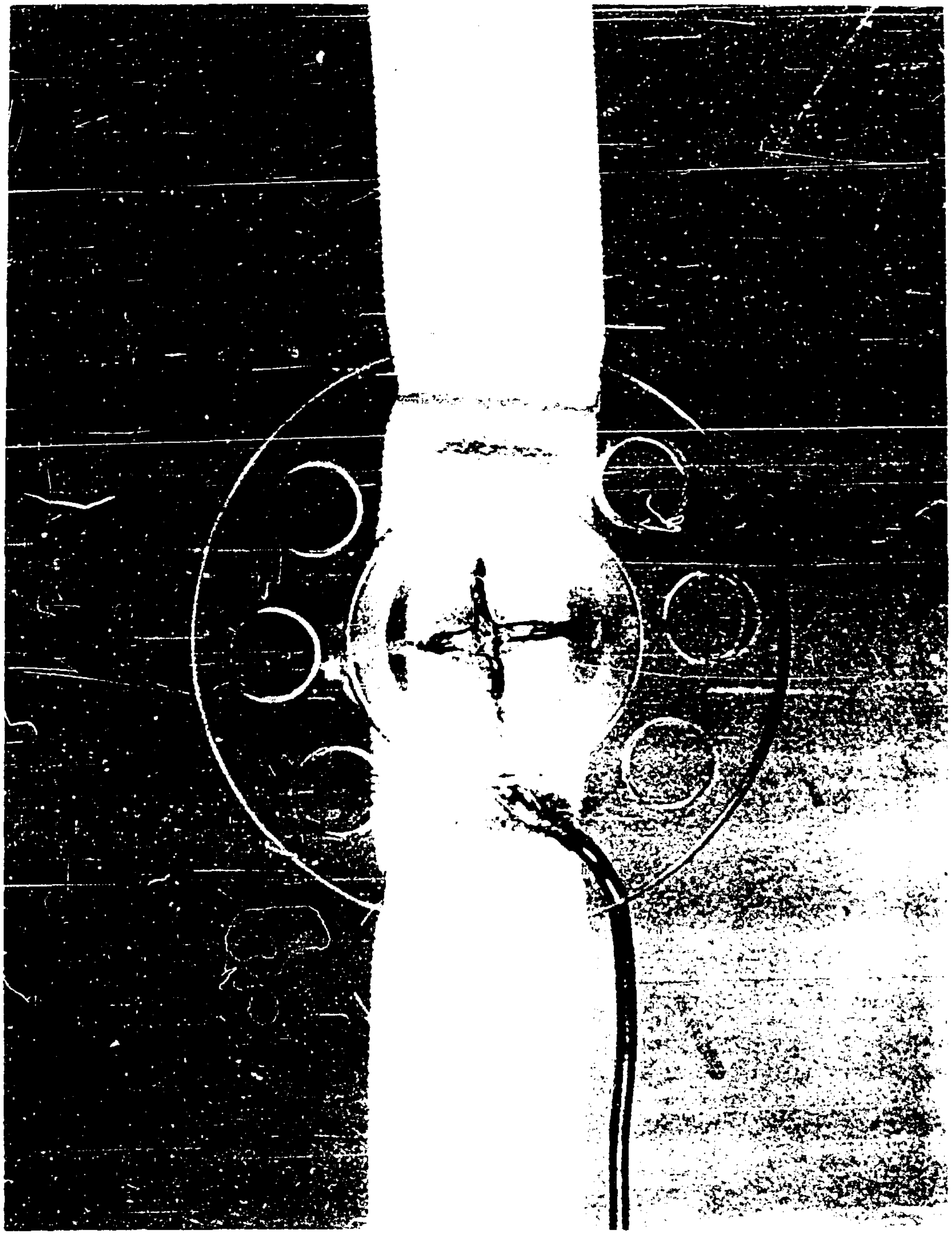

FIGURE 1

LIQUID-JUNCTION ELECTRODE

View looking into cup with copper terminal at bottom. Open side is held against the skin with elastic webbing and wad of absorbent cotton and electrode paste, not shown, makes connection between skin and copper terminal. Diameter of cup, 1 inch; diameter of outer disk, 2 1/2 inches

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APPENDIX B

TABLES

TABLE 1

TEMPERATURES AT VARIOUS POINTS IN HOT ROOM

Location no.	Location	Treadmill belt: Height above	Treadmill belt: Distance from center	Mean temp	Range ±	Mean temp	Range ±	Mean temp	Range ±
		in.		°F					
1	Dry bulb, psychrometer	55	102	85.2	2.2	100.4	2.7	115.1	3.2
2	Air, right of subject	70	74	84.3	2.5	99.7	4.0	114.7	4.0
3	Air. left of subject	70	75	84.3	2.5	99.9	3.2	114.4	4.2
4	Air. left of subject	-13	42	83.8	1.2	94.7	0.5	103.3	0.2
5	Air, left of subject	14	31	84.1	2.0	97.6	1.5	110.0	1.2
6	Air, left of subject	51	81	84.3	3.0	100.1	4.0	114.7	4.2
7	Wall, left of subject	61	86	85.1	0.7	98.4	1.0	111.6	1.2
8	Window, left of subject	44	74	83.5	0.5	94.7	0.7	105.7	1.0
9	Wall, front of subject	83	198	84.9	1.5	98.9	1.5	112.8	2.2
10	Wall, right of subject	79	152	83.6	0.5	96.1	0.5	108.4	0.7
11	Metal door, right of subject	55	147	84.1	0.7	97.0	1.0	109.4	1.5
12	Wall, back of subject	61	163	83.7	0.7	97.0	0.5	113.5	3.2
13	Ceiling	93	104	83.4	1.7	97.5	2.5	114.6	4.5
14	Wood base, right of subject	0	25	85.0	0.5	97.3	0.5	108.6	0.2
15	Metal base, left of subject	0	29	84.4	0.5	96.6	0.5	106.8	0.5
16	Cement floor, front of subject	-29	78	84.8	0.2	90.0	0.0	96.5	0.0
	Av air, 2 to 6			84.2	2.2	98.4	2.6	111.4	2.7
	Av surface, 7 to 15			84.2	0.8	97.1	1.0	110.2	1.7

TABLE 2

INDOOR AIR FLOW WITH PROBE HELD BY SUBJECT

(Subject F. N. C., 10 March 1961)

Activity of subject	Flow for indicated locations of probe				Average flow	Insulation, Ia
	Head position		Knee position			
	Side open	Front open	Side open	Front open		
	ft/min				mph	clo
Stand	16	18	20	22	0.22	—
Walk 2 mph, level	20	28	35	40	0.35	0.84
Walk 3 mph, level	24	34	55	60	0.48	0.75
12% grade	25	35	53	60	0.48	0.75
Arm swinging	—	—	54	130	—	—

TABLE 3

ENVIRONMENTAL CONDITIONS, HEAD TEMPERATURES, AND RATES OF INCREASE OF MEAN BODY TEMPERATURE

Day	Motor psychrometer: Dry bulb, °F	Motor psychrometer: Wet bulb, °F	Motor psychrometer: Vapor pres. mm Hg	Pyrheliometer,* gm-cal/sqcm/min	Black globe,* °F	Man	Hood	Head temp, °F: Walk 1	Head temp, °F: Walk 2	Rise in body temp, °F/hr: Walk 1	Rise in body temp, °F/hr: Walk 2	Man	Hood	Head temp, °F: Walk 1	Head temp, °F: Walk 2	Rise in body temp, °F/hr: Walk 1	Rise in body temp, °F/hr: Walk 2
Part A: Outdoors					Treadmill speed/grade:			2/0	3/12	2/0	3/12			2/0	3/12	2/0	3/12
22 Aug	82.0	78.8	24.4	0.34	101	R	-	97.2	99.2	0.51	5.60	P	+	99.8	101.2	1.21	6.16
26	78.6	67.5	14.3	1.20	109			99.3	100.2	0.25	7.76			99.9	100.8	0.79	4.44
1 Sept	89.0	79.3	23.0	1.14	110			99.6	99.0	0.36	6.60			103.7	111.0	1.47	5.04
8	82.3	74.9	20.1	1.15	103			98.9	101.0	0.46	8.64			96.1	101.0	1.13	5.04
Av	83.0		20.5	1.01	105			98.8	99.9	0.40	7.15			99.9	103.5	1.15	5.17
19 Aug	85.8	74.3	18.8	1.23	114	R	+	108.5	108.4	0.35	4.60	P	-	100.4	101.0	1.75	4.40
25	79.2	69.6	16.1	1.09	103			99.7	101.8	0.29	5.28			95.9	96.4	-0.53	7.28
31	85.7	77.2	21.8	0.85	110			101.4	102.7	1.40	5.92			97.8	98.8	0.78	3.56
7 Sept	81.5	73.5	19.1	1.11	103			98.8	101.0	0.73	9.28			96.1	101.0	1.43	5.60
Av	83.0		19.0	1.07	108			102.1	103.5	0.69	6.27			97.6	99.3	0.86	5.21
Part A: Outdoors					Treadmill speed/grade:			3/0	3/0	3/0	3/0			3/0	3/0	3/0	3/0
17 Aug	82.0	76.0	21.4	0.91	105	R	-	99.4	99.5	2.41	0.08	P	+	101.5	101.2	2.42	0.34
24	80.4	70.7	16.7	1.00	103			100.2	99.8	-0.28	1.30			100.0	99.9	1.38	1.32
30	91.3	79.7	23.0	0.58	108			100.3	97.9	1.98	1.12			102.0	99.2	2.92	0.76
6 Sept	81.4	73.9	19.3	0.98	105			96.8	97.8	0.40	0.51			100.5	99.7	1.39	0.76
Av	83.8		20.1	0.87	105			99.2	98.8	1.12	0.75			101.0	100.0	2.03	0.80
23 Aug	88.8	79.9	23.9	0.82	108	R	+	108.5	108.4	1.58	0.74	P	-	100.3	99.1	2.46	0.92
29	89.2	80.1	23.9	0.99	115			99.7	101.8	2.40	2.10			99.4	100.1	2.42	0.84
2 Sept	86.6	75.8	20.0	1.00	109			101.4	102.7	1.28	0.77			95.8	96.7	1.50	1.00
9	86.5	79.8	24.3	0.88	106			98.8	101.0	1.44	1.73			98.4	99.7	1.74	1.82
Av	87.8		23.0	0.92	110			102.1	103.5	1.68	1.34			98.5	98.9	2.03	1.15
Part B: Indoors					Treadmill speed/grade:			2/0	3/12	2/0	3/12			2/0	3/12	2/0	3/12
14 Sept	99.1	79.3	20.2			R	-	96.7	94.9	0.85	4.2	P	+	99.3	102.6	1.93	3.0
15	99.2	79.9	20.9			R	+	99.3	97.9	1.16	4.8	P	-	98.6	96.6	1.20	4.8
23	115.6	82.6	19.5			R	-	100.6	99.9	1.25	1.2	P	+	103.8	100.7	2.15	1.2
26	115.4	82.8	19.7			R	+	103.4	100.5	2.09	1.2	P	-	101.5	100.3	2.10	2.4
29	114.1	83.3	20.5			R	+	101.6	98.0	1.88	2.4	P**	+	102.3	99.8	2.30	0.0
30	114.6	82.6	19.8			R**	+	101.5	99.2	1.86	1.2	P	+	102.0	100.1	2.32	0.0
3 Oct	85.5	75.7	20.0			R	-	91.7	93.6	0.0	6.8	P	+	95.9	96.9	1.07	6.8
4	85.2	75.4	19.9			R	+	96.4	96.9	0.0	4.8	P	-	94.2	93.7	0.45	5.2
Av	85.4		20.0			R	±	94.1	95.3	0.0	5.8	P	±	95.1	95.3	0.76	6.0
Av	99.2		20.6			R	±	98.0	96.4	1.01	4.5	P	±	99.0	99.6	1.57	3.9
Av	114.9		19.9			R	±	101.8	99.4	1.77	1.5	P	±	102.4	100.2	2.22	0.9
Part B: Indoors					Treadmill speed/grade:			3/0	3/0	3/0	3/0			3/0	3/0	3/0	3/0
12 Sept	101.0	81.9	22.8			R	-	96.8	97.1	0.75	0.88	P	+	98.2	100.8	1.35	1.33
13	99.5	80.0	21.0			R	+	99.2	99.3	2.18	1.80	P	-	97.9	98.7	1.69	1.55
19	115.3	82.2	19.0			R	-	102.5	—	3.23	—	P	+	102.7	—	3.82	—
21	115.2	82.4	19.3			R	+	104.0	—	2.90	—	P	-	101.0	—	3.33	—
27	115.4	82.8	19.7			R	-	101.4	—	3.05	—	P	+	104.6	—	3.70	—
28	114.3	84.6	22.5			R	+	103.8	—	3.63	—	P	-	103.8	—	3.80	—
5 Oct	84.6	75.9	20.5			R	-	91.6	90.5	0.32	0.86	P	+	95.6	96.9	1.22	1.35
6	85.0	75.5	20.2			R	+	96.7	97.2	1.16	0.00	P	-	93.7	95.2	1.25	0.82
Av	84.8		20.4			R	±	94.2	93.9	0.74	0.43	P	±	94.7	96.1	1.24	1.09
Av	100.3		21.9			R	±	98.0	98.2	1.47	1.34	P	±	98.1	99.8	1.82	1.44
Av	115.1		20.1			R	±	102.9		3.20		P	±	103.0		3.66	

* These values do not apply to the indoor experiments.

** Outlet valve vented outside hood.

TABLE 4

SUMMARY OF HEART RATES, BEATS PER MINUTE

Day	Man	Hood	Air temp, °F	Duration of walks, min		Heart rate, first walk			Heart rate, second walk		
				First	Second	Initial	Final	Mean	Initial	Final	Mean
Part A: Outdoors				Treadmill speed/grade:		2/0	2/0	2/0	3/12	3/12	3/12
22 Aug	R	-	82.0	55	15	102	110	108	156	184	172
26	R	-	78.6		15	96	116	109	120	184	161
1 Sept	R	-	89.0		15	100	109	106	138	184	167
8	R	-	82.3		15	94	124	113	133	194	173
19 Aug	P	-	85.8		11	116	96	93	142	184	167
25	P	-	79.2		15	80	82	80	118	168	149
31	P	-	85.7		15	80	88	84	132	176	161
7 Sept	P	-	81.5		15	76	80	80	110	172	147
19 Aug	R	+	85.8		15	116	120	119	140	184	169
25	R	+	79.2		15	112	120	114	140	176	165
31	R	+	85.7		12	100	106	105	144	188	167
7 Sept	R	+	81.5		11	92	107	103	133	176	159
22 Aug	P	+	82.0		15	86	94	87	144	184	164
26	P	+	78.6		15	88	96	87	112	180	156
1 Sept	P	+	89.0		15	88	113	98	135	189	170
8	P	+	82.3		13	106	111	103	117	192	169
Av	RP	-	83.0			93	101	97	131	181	162
Av	RP	+	83.0			99	108	102	133	186	165
Part A: Outdoors				Treadmill speed/grade:		3/0	3/0	3/0	3/0	3/0	3/0
17 Aug	R	-	82.0	55	55	116	124	121	116	120	122
24	R	-	80.4		55	108	116	114	108	120	115
30	R	-	91.3		55	104	132	124	124	140	133
6 Sept	R	-	81.4		55	103	123	115	118	122	119
23 Aug	P	-	88.8		55	88	134	108	116	152	133
29	P	-	89.2		30	88	148	121	132	164	153
2 Sept	P	-	86.6		55	78	121	100	108	136	121
9	P	-	86.5		30	88	135	117	132	157	141
23 Aug	R	+	88.8		55	112	130	121	124	140	132
29	R	+	89.2		25	104	144	127	136	160	147
2 Sept	R	+	86.6		55	98	128	116	116	142	130
9	R	+	86.5		30	108	136	125	136	157	144
17 Aug	P	+	82.0		55	92	124	111	124	140	133
24	P	+	80.4		55	94	108	101	116	124	116
30	P	+	91.3		18	96	164	127	128	140	139
6 Sept	P	+	81.4		55	94	120	105	109	142	142
Av	RP	-	85.8			97	128	114	119	139	130
Av	RP	+	85.8			100	132	117	124	143	135

TABLE 4 (contd)

Day	Man	Hood	Air temp, °F	Duration of walks, min: First	Duration of walks, min: Second	Heart rate, first walk: Initial	Heart rate, first walk: Final	Heart rate, first walk: Mean	Heart rate, second walk: Initial	Heart rate, second walk: Final	Heart rate, second walk: Mean
Part B: Indoors					Treadmill speed/grade:	3/0	3/C	3/0	3/0	3/0	3/0
12 Sept	R	-	101.0	55	55	122	140	130	136	160	145
13	P	-	99.5		55	102	148	120	132	172	154
13	R	+	99.5		42	112	148	128	136	148	144
12	P	+	101.0		39	118	144	130	136	158	145
19 Sept	R	-	115.3	45	—	127	154	141			
21	P	-	115.2	51	—	104	178	139			
27	R	-	115.4	55	—	112	190	143			
28	P	-	114.3	43	—	112	174	150			
21 Sept	R	+	115.2	55	—	117	172	138			
19	P	+	115.3	30	—	108	164	139			
28	R	+	114.3	55	—	116	172	150			
27	P	+	115.4	40	—	113	164	132			
5 Oct	R	-	84.6	5[illegible]	55	113	128	118	124	136	130
6	P	-	85.0		55	103	136	123	140	156	149
6	R	+	85.0		10	103	124	117	120	140	130
5	P	+	84.6		38	108	148	122	138	148	148
Av	RP	-	84.8			108	132	121	132	146	140
		+	184.8			108	136	120	129		
Av		-	100.3			112	144	125	134	166	150
		+	100.3			115	146	129	136		
Av		-	115.1	49		114	174	143	—		
		+	115.1	45		114	168	140	—		
Part B: Indoors					Treadmill speed/grade:	2/0	2/0	2/0	3/12	3/12	3/12
14 Sept	R	-	99.1	55	12	100	124	110	140	180	164
15	P	-	99.2		11	101	140	117	163	192	180
15	R	+	99.2		5	112	130	119	152	184	172
14	P	+	99.1		13	108	140	120	156	200	183
23 Sept	R	-	115.6		7	104	136	116	128	180	154
26	P	-	115.4		10	104	160	126	148	188	168
25	R	+	115.4		5	112	156	133	156	188	172
23	P	+	115.6		7	100	170	129	150	199	180
30 Sept*	R	+	114.6		4	105	137	119	135	180	158
29 Sept*	P	+	114.1		5	108	170	135	180	194	189
29	R	+	114.1		5	106	138	119	157	180	172
30	P	+	114.6		4	88	164	123	148	188	168
3 Oct	R	-	85.5		14	105	115	107	123	181	163
4	P	-	85.2		15	88	99	93	132	178	164
4	R	+	85.2		8	108	116	115	136	178	157
3	P	+	85.8		14	89	107	97	118	187	164
Av	RP	-	85.4			97	107	100	128	180	164
Av	RP	+	85.4			99	112	106	127	184	161
Av	RP	-	99.2			101	132	114	152	186	172
Av	RP	+	99.2			110	135	120	154	192	178
Av		-	115.5			104	148	122	138	18[illegible]	161
Av		+	115.5			106	163	131	153	194	176
Av*		+	114.4			107	154	127	158	187	174
Av		+	114.4			97	151	121	153	184	170

* Outlet valve vented outside hood.

TABLE 5

SUMMARY OF BODY WEIGHT

Day	Man	Hood	Air temp, °F	Duration of walk, min: First, Fully clothed	First, Total	Second, Fully clothed	Second, Total	Nude weight, kg: Initial	Loss	Clothed weight loss: 1st walk, total gm	2nd walk, Total gm	2nd walk, Rate, gm/min	Gain in wt of clothing, gm	Remarks
Part A: Outdoors								Treadmill speed/grade:		2/0	3/12	3/12		
22 Aug	R	-	82.0	55	55	15	15	72.14	1.04	300	178	11.9	923	
26			78.6			15		72.02	0.88	326	244	16.3	314	
1 Sept			89.0			15		72.49	1.36	488	268	17.9	603	
8			92.3			15		72.49	1.02	440	231	15.4	353	
19 Aug	P	-	85.8	55	55	11	15	79.72	1.79	556	263	17.5	972	Headgear off at 11 min
25			79.2			15		79.21	1.12	396	181	12.1	539	
31			85.7			15		79.48	1.46	603	241	16.1	820	
7 Sept			81.5			15		79.33	1.21	584	203	13.5	424	
19 Aug	R	+	85.8	55	55	15	15	71.65	1.39	483	246	16.4	658	Difficult breathing
25			79.2			15	15	71.58	0.83	272	—		—	
31			85.7			12	12	71.65	1.61	346	169	14.1	1,097	Stood last 3 min, difficult breathing
7 Sept			81.5			11	11	72.08	0.85	363	167	15.2	316	
22 Aug	P	+	82.0	55	55	15	15	80.15	1.72	265	270	18.0	1,185	
26			78.6			15	15	79.19	1.51	466	288	19.2	754	
1 Sept			89.0			15	15	79.75	1.99	652	343	22.9	999	
8			82.3			10	15	80.09	1.83	572	275	18.3	1,078	Hood off at 10 min
Av	RP	-	83.1	55	55	15		75.86	1.24	462	—	15.1	619	
Av	RP	+	83.1	55	55	14		75.76	1.48	[illegible]	—	17.7	870	
Part A: Outdoors								Treadmill speed/grade:		3/0	3/0	3/0		
17 Aug	R	-	82.0	55	55	55	55	72.08	1.55	460	700	12.7	370	
24			80.4			55		71.74	1.37	461	490	8.9	419	
30			91.3			55		71.86	2.01	501	698	12.7	810	
6 Sept			81.4			55		71.19	1.52	573	510	9.3	437	
23 Aug	P	-	88.8	55	55	55	55	80.70	3.00	722	936	17.0	1,342	
29			[illegible]			30	30	79.90	2.78	611	492	16.4	1,673	
2 Sept			86.6			55	55	79.64	2.46	692	853	15.5	914	
9			86.5			30	30	79.70	2.37	606	471	15.7	1,293	
23 Aug	R	+	88.8	55	55	55	55	72.22	2.15	212	749	13.6	1,190	
29			79.2			25	25	71.42	1.80	518	271	10.8	1,003	
2 Sept			86.6			55	55	72.61	2.17	564	688	12.5	914	
9			86.5			30	30	72.46	1.86	471	362	12.1	1,024	
17 Aug	P	+	82.0	55	55	55	55	79.62	2.58	451	765	13.9	1,367	
24			80.4			55	55	79.57	2.32	402	846	15.4	1,076	
30			91.3			18	18	79.50	2.58	610	322	17.9	1,650	Tired
6 Sept			81.4			55	55	79.76	2.68	656	714	13.0	1,313	
Av	RP	-	85.8	55	55	49		75.79	2.13	578		13.5	907	
Av	RP	+	85.8	55	55	44		75.90	2.27	466		13.7	1,192	

TABLE 5 (contd)

Day	Man	Hood	Air temp, °F	Duration of walk, min: First, Fully clothed	First, Total	Second, Fully clothed	Second, Total	Nude weight, kg: Initial	Loss	Clothed weight loss: 1st walk, total gm	2nd walk, Total gm	2nd walk, rate, gm/min	Gain in wt of clothing, gm	Remarks
Part B: Indoors								Treadmill speed/grade:		3/0	3/0	3/0		
12 Sept	R	-	101.0	55	55	55	55	72.22	2.22	515	638	11.6	1,066	
13	P	-	99.5			55	55	80.02	3.34	519	688	12.5	2,135	
13	R	+	99.5			42	55	72.26	2.38	573	590	10.7	1,221	Headgear and pack off at 42 min
12	P	+	101.0			39	55	80.23	3.30	607	706	12.8	1,984	Mask and hood off at 39 min, replaced helmet
19 Sept	R	-	115.3	45	45			72.24	1.33	504		11.2	822	
21	P	-	115.2	51	51			80.13	2.21	686		13.5	1,521	Headgear off at 51 min
27	R	-	115.4	55	55			72.36	1.49	478		8.7	1,014	
28	P	-	114.3	43	52			79.99	2.11	668		12.8	1,437	Headgear off at 43 min
21 Sept	R	+	115.2	55	55			72.42	2.29	506		9.2	1,787	
19	P	+	115.3	35	45			80.28	2.03	712		15.8	1,322	Head cold, headgear off at 35 min
28	R	+	114.3	55	55			72.59	1.52	507		9.2	1,014	Headgear off at 35 min
27	P	+	115.4	38	43			79.95	1.88	467		10.9	1,416	Helmet off at 38 min, stomach upset (lunch)
5 Oct	R	-	84.6	55	55	55	55	72.95	1.63	262	497	9.0	875	
6	P	-	85.0			55	55	80.94	2.90	453	537	9.8	1,912	
6	R	+	85.0			10	36	73.10	1.63	296	254	7.0	1,080	Chafing in crotch, pack off at 10 min
5	P	+	84.6			38	55	81.00	2.19	374	547	9.9	1,266	Foot fungus, headgear off at 38 min, pack off at 43 min
Av	RP	-	84.8	55		55		76.94	2.27	358		9.4	1,394	
Av	RP	+	84.8	55		24		77.05	1.91	335		8.5	1,173	
Av	RP	-	100.3	55		55		76.12	2.78	517		12.1	1,601	
Av	RP	+	100.3	55		41		76.24	2.84	590		11.8	1,603	
Av	RP	-	115.1	51				76.18	1.79	584		11.6	1,199	
Av	RP	+	115.1	46				76.31	1.93	548		11.3	1,385	
Part B: Indoors								Treadmill speed/grade:		2/0	3/12	3/12		
14 Sept	R	-	99.1	55	55	12	12	78.08	1.16	317	138	11.5	·07	Cramp in right thigh
15	P	-	99.2			11	11	79.83	2.00	387	235	21.4	1,379	
15	R	+	99.2			5	5	72.27	1.42	264	215	43.0	941	
14	P	+	99.1			9	13	79.27	2.10	370	215	16.5	1,510	Headgear off at 9 min, not enough air
23 Sept	R	-	115.6			7	7	72.40	1.37	407	157	22.4	810	Legs gave out
26	P	-	115.4			10	10	80.04	2.25	389	225	22.5	1,633	Winded
26	R	+	115.4			5	5	72.22	1.60	474	105	21.0	1,016	Legs and breathing
23	P	+	115.6			7	7	79.84	2.35	445	330	47.1	1,579	Blowing out on expiration
30 Sept	R	+*	114.6			4	4	72.61	1.61	433	113	28.3	1,068	
29	P	+*	114.1			5	5	79.78	2.34	491	178	35.6	1,666	
29	R	+	114.1			5	5	72.63	1.53	412	114	22.8	1,005	
30	P	+	114.6			4	4	79.93	2.50	607	150	37.5	1,739	
3 Oct	R	-	85.5			14	14	72.11	1.02	288	127	9.1	607	
4	P	-	85.2			15	15	81.36	1.56	302	226	15.1	1,036	
4	R	+	85.2			7	9	72.85	0.80	206	139	15.3	459	Breathing resistance
3	P	+	85.5			14	14	81.44	1.77	338	195	13.9	1,235	
Av	RP	-	85.4	55		15		76.74	1.29	295		12.1	822	
Av	RP	+	85.4	55		11		77.15	1.29	272		14.6	847	
Av	RP	-	99.2	55		12		75.96	1.58	352		16.5	1,043	
Av	RP	+	99.2	55		9		75.77	1.76	317		29.8	1,226	
Av	RP	-	115.5	55		9		76.22	1.81	398		22.5	1,222	
Av	RP	+	115.5	55		6		76.03	1.98	460		34.1	1,296	
Av	RP	+*	114.6	55		5		76.20	1.98	462		32.0	1,367	
Av	RP	+	114.4	55		5		76.28	2.02	510		30.2	1,372	

* Unpressurized.

TABLE 6

SUMMARY OF BODY TEMPERATURES

Day	Man	Hood	Air temp, °F	Duration of walk, min		First walk						Second walk					
						Average skin temp, °F			Rectal temp, °F			Average skin temp, °F			Rectal temp, °F		
				1st	2nd	Initial	Final	Mean	Initial	Final	Mean	Initial	Final	Mean	Initial	Final	Mean
Part A: Outdoors			Treadmill speed/grade:			2/0	2/0	2/0	2/0	2/0	2/0	3/12	3/12	3/12	3/12	3/12	3/12
22 Aug	R	-	82.0	55	15	94.0	95.4	95.0	99.5	99.8	99.5	93.7	96.6	95.1	100.3	101.0	100.6
26	R		[illegible]		15	93.5	93.5	93.9	99.8	99.7	99.6	92.2	95.2	94.3	99.9	100.8	100.4
1 Sept	R	-	89.0		15	94.2	95.5	95.4	[illegible]	99.8	99.6	94.6	96.5	95.8	99.8	100.9	100.4
8	R	-	82.3		15	93.0	94.2	93.8	99.5	99.4	99.4	92.8	95.6	94.5	99.6	100.9	100.3
19 Aug	P	-	85.8	55	11	92.6	97.2	95.6	100.4	100.5	100.3	96.2	98.1	97.2	100.7	101.4	101.0
25	P	-	79.2		15	92.3	92.1	92.4	100.2	99.6	99.7	91.2	95.3	93.0	99.8	106.7	100.2
31	P	-	85.7		15	90.1	96.0	94.2	100.2	100.0	100.0	93.7	95.2	94.5	100.2	100.8	100.5
7 Sept	P	-	81.5		15	90.1	94.0	92.4	100.2	99.7	99.8	93.1	96.1	94.8	99.8	100.4	100.1
19 Aug	R	+	85.8	55	15	95.2	96.3	96.3	100.1	100.4	100.1	95.6	96.7	96.6	100.5	101.3	100.8
25	R	+	79.2		15	92.6	92.6	93.2	99.7	99.8	99.7	90.6	92.6	91.4	100.0	101.2	100.6
31	R	+	85.7		12	93.2	96.4	95.1	99.7	100.1	99.7	94.0	96.4	95.3	100.3	101.2	100.8
7 Sept	R	+	81.5		11	93.5	92.5	92.6	98.7	98.9	98.7	91.8	95.4	94.1	99.3	99.9	99.7
22 Aug	P	+	82.0	55	15	92.1	96.9	95.5	99.9	100.1	99.8	[illegible]	98.1	96.8	100.4	101.3	100.8
26	P	+	78.6		15	91.7	94.8	93.8	100.5	100.0	100.1	93.8	96.3	95.1	100.3	100.7	100.5
1 Sept	P	+	89.0		15	93.1	97.9	96.6	100.3	100.6	100.2	97.0	99.0	97.9	100.7	101.6	101.2
8	P	+	82.3		13	92.3	94.9	93.8	99.8	100.0	99.8	96.0	97.9	97.1	100.5	101.2	100.9
Av	RP	-	83.0	55	15	92.5	94.7	94.1	99.9	99.8	99.7	93.4	96.2	94.9	100.0	100.9	100.4
Av	RP	+	83.0	55	14	93.0	[illegible]	94.6	99.8	100.0	99.8	94.3	96.6	95.5	100.3	101.1	100.7
Part A: Outdoors			Treadmill speed/grade:			3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0
17 Aug	R	-	82.0	55	55	93.1	96.1	95.7	99.4	100.5	99.9	92.5	92.5	92.7	100.6	100.6	100.6
24			80.4		55	92.3	93.8	93.7	99.4	100.1	99.7	91.2	93.4	92.4	100.2	100.8	100.6
30			91.3		55	93.3	97.4	96.4	99.5	100.6	100.1	95.9	98.0	97.0	101.0	101.5	101.2
6 Sept			81.4		55	94.5	94.6	94.7	99.6	99.8	99.7	93.9	95.2	94.4	100.0	100.3	100.1
23 Aug	P	-	88.8		55	92.4	97.7	96.3	99.8	100.7	100.1	96.4	97.2	97.0	101.2	101.7	101.3
29			89.2		30	93.3	99.0	97.3	99.8	101.0	100.1	98.4	98.2	98.1	101.6	102.4	102.0
2 Sept			86.6		55	91.6	97.6	95.6	100.4	100.5	100.1	96.5	97.5	97.2	100.7	101.5	101.1
9			86.5		30	91.7	98.1	96.2	100.1	100.4	100.0	95.6	97.7	97.2	100.7	101.4	101.0
23 Aug	R	+	88.8		55	93.6	96.9	96.2	98.9	100.3	99.6	96.1	96.8	96.5	100.6	100.7	100.6
29			89.2		25	95.0	98.5	97.0	99.4	101.3	100.3	97.6	98.4	98.0	101.5	102.6	102.0
2 Sept			86.6		55	92.1	94.9	94.7	99.4	99.7	99.5	94.4	95.9	95.3	100.3	100.8	100.5
9			86.5		30	93.6	96.7	95.6	99.6	100.5	99.9	95.8	96.8	96.2	100.5	101.3	100.9
17 Aug	P	+	82.0		55	93.1	97.7	96.4	99.8	100.6	100.0	96.9	95.8	96.9	100.8	101.4	101.1
24			80.4		55	[illegible]	96.4	94.5	99.9	100.3	99.9	94.7	95.8	95.0	100.6	101.3	100.9
30			91.3		18	92.3	97.7	96.8	100.1	101.5	100.5	95.1	95.8	95.6	101.9	102.0	101.9
6 Sept			81.4		55	92.6	97.0	95.9	100.3	100.6	100.3	96.2	97.3	96.9	100.8	101.4	101.0
Av	RP	-	85.8	55	48	92.8	96.8	95.7	99.8	100.5	100.0	[illegible]	95.2	95.8	100.8	101.3	101.0
Av	RP	+	85.8	55	43	93.0	97.0	95.9	99.7	100.6	100.0	95.9	[illegible]	96.3	100.9	101.4	101.1

TABLE 6 (contd)

Day	Man	Hood	Air temp, °F	Duration of walk, min		First walk						Second walk					
						Average skin temp, °F			Rectal temp, °F			Average skin temp, °F			Rectal temp, °F		
				1st	2nd	Initial	Final	Mean	Initial	Final	Mean	Initial	Final	Mean	Initial	Final	Mean
Part B: Indoors			Treadmill speed/grade:			2/0	2/0	2/0	2/0	2/0	2/0	3/12	3/12	3/12	3/12	3/12	3/12
14 Sept	R	-	99.1	55	12	93.4	95.9	95.2	98.3	99.3	98.9	94.0	95.1	94.5	99.6	100.0	99.8
15	P	-	99.2		11	94.9	98.1	96.9	99.4	100.2	99.7	96.7	98.2	97.4	100.6	101.0	100.8
15	R	+	99.2		5	93.7	96.3	95.7	99.6	100.1	99.5	94.9	95.5	95.2	100.3	100.6	100.5
14	P	+	99.1		13	94.0	97.2	96.8	99.2	100.3	99.5	95.4	96.2	95.8	100.9	101.3	101.1
23 Sept	R	-	115.6	55	7	96.0	98.3	98.0	99.6	100.2	99.6	95.8	96.2	96.0	100.5	100.6	100.5
26	P	-	115.4		10	95.4	99.0	97.7	99.8	100.4	99.7	97.8	98.9	98.4	101.1	101.1	101.1
26	R	+	115.4		5	96.8	98.5	97.8	99.5	100.8	99.9	97.3	97.4	97.4	101.3	101.4	101.4
23	P	+	115.6		7	95.9	99.4	98.3	100.5	100.6	100.1	97.4	97.9	97.7	101.6	101.5	101.6
30	R	+*	114.6	55	4	94.4	98.3	97.3	99.0	100.9	100.0	96.6	97.2	96.8	101.3	101.2	101.3
29	P	+*	114.1		5	94.4	99.1	97.4	100.4	101.2	100.4	96.9	97.1	97.0	100.6	100.6	100.6
29	R	+	114.1		5	94.6	98.6	97.4	100.0	100.7	100.0	98.2	98.8	98.5	100.0	100.0	100.0
30	P	+	114.6		4	95.1	99.8	97.9	99.5	101.2	100.2	98.6	99.0	98.8	102.0	101.9	101.9
3 Oct	R	-	85.5	55	14	94.3	93.9	94.3	99.6	99.9	99.7	92.2	95.3	93.8	99.8	100.9	100.3
4	P	-	85.2		15	94.3	96.5	95.8	100.0	99.8	99.8	95.2	97.8	96.7	99.9	100.5	100.2
4	R	+	85.2		8	94.9	95.4	95.3	99.5	100.0	99.7	93.9	94.8	94.4	99.9	100.1	100.0
3	P	+	85.5		14	93.4	97.0	95.7	99.8	99.5	99.5	95.1	98.2	96.8	99.6	100.6	100.1
Av	RP	-	85.4	55	15	94.3	95.2	95.1	99.8	99.9	99.8	93.7	96.6	95.3	99.9	100.7	100.3
Av	RP	+	85.4	55	11	94.2	96.2	99.5	99.7	99.8	99.6	94.5	95.6	95.6	99.8	100.4	100.1
Av	RP	-	99.2	55	12	94.2	97.0	96.1	98.9	99.8	99.3	95.4	96.7	96.0	100.1	100.5	100.3
Av	RP	+	99.2	55	9	93.9	96.8	96.0	99.4	100.2	99.3	95.2	95.9	95.5	100.6	101.0	100.8
Av	RP	-	115.5	55	9	95.7	98.7	97.9	99.7	100.3	99.7	96.8	97.6	97.2	100.8	100.9	101.8
Av	RP	+	115.5	55	6	96.4	99.0	98.1	99.9	100.8	100.0	97.4	97.7	97.6	101.5	101.5	101.5
Av	RP	+*	114.4	55	5	94.4	98.7	97.4	99.7	101.1	100.2	96.8	97.2	96.9	101.0	100.9	101.0
Av	RP	+	114.4	55	5	94.9	99.2	97.7	99.8	101.0	100.1	98.4	98.9	98.7	101.0	101.0	101.0
Part B; Indoors			Treadmill speed/grade ;			3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0
12 Sept	R	-	101.0	55	55	92.9	95.7	95.2	99.5	100.6	100.1	95.0	95.6	95.7	100.7	101.8	101.3
13	P	-	99.5	55	55	93.5	97.5	96.3	99.5	100.3	99.6	96.4	97.9	97.5	100.7	102.1	101.3
13	R	+	99.5	55	42	94.6	97.4	96.3	99.1	100.7	99.8	96.8	97.8	97.2	100.9	102.2	101.5
12	P	+	101.0	55	39	94.3	97.9	97.1	100.0	100.7	100.1	97.3	98.0	97.6	101.0	101.7	101.3
19 Sept	R	-	115.3	45	—	93.5	98.7	97.2	100.3	101.4	100.6						
21	P	-	115.2	51	—	95.2	100.1	98.3	100.0	101.4	100.3						
27	R	-	115.4	55	—	97.0	99.1	98.3	100.5	101.5	100.5						
28	P	-	114.3	43	—	93.9	99.9	97.3	99.8	101.7	100.4						
21 Sept	R	+	115.2	55	—	94.5	98.8	97.5	99.6	101.8	100.4						
19	P	+	115.3	30	—	92.9	99.6	97.7	100.3	101.5	100.4						
28	R	+	114.3	55	—	94.3	99.3	97.7	99.4	101.7	100.3						
27	P	+	115.4	40	—	95.4	98.8	98.0	100.2	100.8	100.1						
5 Oct	R	-	84.6	55	55	92.8	94.9	94.7	99.6	100.4	100.0	93.8	94.9	94.6	100.5	101.2	100.9
6	P	-	85.0	55	55	93.0	97.6	96.4	99.9	100.6	100.2	97.4	97.9	97.5	100.8	101.7	101.3
6	R	+	85.0	55	10	92.7	95.1	94.5	99.3	100.3	99.8	95.0	94.7	94.8	100.4	100.6	100.5
5	P	+	84.6	55	38	92.3	97.2	95.8	100.4	100.8	100.5	96.4	96.8	96.7	101.0	101.8	101.4
Av	RP	-	84.8	55	55	92.9	96.3	95.6	99.8	100.5	100.1	95.6	96.4	96.1	100.7	101.5	101.1
Av	RP	+	84.8	55	24	92.5	96.2	95.2	99.9	100.6	100.2	95.7	95.8	95.8	100.7	101.2	100.9
Av	RP	-	100.3	55	55	93.2	96.6	95.8	99.5	100.5	99.9	95.7	96.4	96.6	100.7	102.0	101.3
Av	RP	+	100.3	55	41	94.5	97.7	96.7	99.6	100.7	100.0	97.1	98.0	97.4	101.0	102.0	101.4
Av	RP	-	115.1	49	—	94.9	99.5	97.8	100.2	101.5	100.5						
Av	RP	+	115.1	45	—	94.3	99.1	97.7	99.9	101.5	100.3						

* Unpressurized.

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Physiology Division, U. S. Army Chemical Research and Development Laboratories, Army Chemical Center, Maryland

CONTRIBUTION OF THE E33 HOOD TO HEAT STRESS ON MEN WEARING CBR PROTECTIVE CLOTHING — F. N. Craig, E. G. Cummings, and P. D. Bales

CRDLR 3101, December 1961
Task 4C80-01-005-01, UNCLASSIFIED REPORT

The E33 hood was attached to the M17 mask and worn with the two-layer permeable protective clothing assembly by men walking indoors at 85°, 100°, and 115°F, and outdoors at 85°F in the sunshine. The heat stress of the hood was assessed by measuring the physiological strain produced by the assembly with and without the hood. The contribution of the sunshine to the heat stress was assessed by adjusting the indoor condition to produce the same degree of physiological strain observed outdoors in the sun.

Hood, E33

Heat Stress — Protective Clothing

Heat Stress — Sunshine

Protective Clothing — Heat Stress

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